The

MICROCEPHALIC IDIOT.

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General Statement.

The subject of microcephaly has excited the greatest interest amongst all those who have been engaged in the study of medicine ever since 1867 when Carl Vogt first gave to this class of idiot the term "ape-men", and put forward the theory that the condition must be regarded as a partial atavism "in which a phylogenetic stage in the evolutionary development of man is reproduced". (Vogt, Uber die Microcephalen oder Affen-Menschen, Archiv. fur Anthropologie, Bb. II 1869.) He had not, however, any microcephalic brain at his disposal and thus he based his conclusions upon observations made on casts of the interior of crania. Observations of such far reaching importance based upon such slight and faulty evidence had the effect of rather repelling subsequent workers, and thus we find a strong wave of feeling in the opposite direction, the theory of a partial or general atavism being denied and the condition deing ascribed to purely pathological causes.

In 1895, however, Cunningham and Telford-Smith (Trans. of Royal Dublin Society; p. 287) published a paper upon "the Brain of the Microcephalic Idiot" in which a most complete account is given of the result of an examination of the brains of two microcephalic idiots, Fred and Joe, and in which a return is made to the theory of Vogt that the condition is due to an atavism, although the view which they put forward is of quite a different nature than that of Vogt, and which is based upon a complete examination of the fissures and convolutions of these two brains, and thus the whole question is put upon a sound accurate and scientific basis.

Since this paper appeared there have been a large number of further contributions to this subject, most of which consist of isolated observations upon individual cases without any attempt being made to bring them into comparison with other reported cases, or to bring our knowledge of this most interesting subject into correlation with our present knowledge of the nervous system, for, during the last few years there is no subject in which our knowledge has increased at a more rapid rate than in the case of the nervous system of man and the apes.

The following paper is based upon a study of the whole nervous system of a microcephalic idiot named Robert Lindsay, who died at the Larbert Institution at the age of I9 from phthisis. The material was obtained from this case was of a most complete nature and belongs to Professor Cunningham. It consists of a cast of the head, of the skull and of the brain and spinal cord, all of which have been carefully described. For convenience of description I have divided the nervous system into three parts;-

I. The cerebrum,

which has been examined macroscopically;

2. The mesencephalon, cerebellum, pons and medulla,

which have been cut into serial sections; and

3. The spinal cord,

which has been fully examined microscopically.

I have examined each of these in turn, and have then proceeded to what is the main object of this work, namely, to make a complete comparative study of all those cases of true micro--cephalic idiocy on record and thus to determine by means of comparison the true nature of the different fissures of the microcephalic brain and more especially to try and show that true microcephalic brains do present certain common morphological features, and thus belong to a definite type forming a natural group outside the domain of pathology.

In making a comparative study of the many cases of microcephaly on record, I may here point out that, owing to the great advane which have been made in our knowledge of the brain since these were published, I have not hesitated to rename and correct many of the fissures on these brains, and to put forth ~~a rath~~ rather different view of the whole subject which is more in accordance with our present knowledge than any of the views which have yet been published.

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LITERATURE.

Th. Willis; Cerebri anatome, cui accessit nervorum descriptio et usus. Londini, 1664.

This is the earliest description of a microcephalic brain and is, as one might expect, very incomplete.

Marshall and Gore; The Anthropological Review, Vol. I., p. 168. 1863.

Here a description is given of a true microcephalic brain, which is one of the smallest on record, weighing only 283 grammes. It belonged to a woman aged 42, who appears to have been a typical microcephalic idiot.

Carl Vogt; Uber die Mikrocephalen oder Affenmenschen. Archiv. für Anthropologie. Bd. II, p. 129. 1867.

This paper consists of an elaborate memoir, which marks one of the well-defined landmarks in the evolution of opinion which has taken place in connection with this subject. Even before it was possible to institute any structural comparison, observers seem to have been struck with a resemblance to lower animals, (Blumenbach 1812; Laycock, 1863), Vogt, in this most elaborate memoir, however, first applied to microcephalic idiots the term "ape-men", and 'tried to prove that the condition must be looked upon as a partial atavism in which a phylogenetic stage in the evolutionary development of man is reproduced'. It is very important, however, that we should clearly understand the meaning of the term "atavism" as used by Vogt. He considered that a simple arrest of development necessarily involved an atavistic condition. There is no doubt that this paper marks an epoch in our knowledge of this subject; but his deductions are drawn from evidence which had very little foundation in fact. He had no microcephalic brains at his disposal, and he drew his deduct--tions from a study of crania and casts of the interior of crania. It thus very soon became apparent that his results were of too sweeping a character; and consequently subsequent observers were repelled by conclusions based upon such insufficient evidence and denied all suggestions of an atavistic origin for this condition, insisting that it was a purely pathological condition. From our present knowledge, however, we now know that this idea of Vogt is far nearer the truth than the pathological theory, and in fact, the question was very neatly summed up by Giacomini several years later, when he stated that the pathological theory was ""less true than the theory of Vogt".

Bischoff; Anatomische Beschreibung eines mikrocephalen 8jährigen Mädchens, Helene Becker aus Offenbach. Abhandl. d. k. bayr. Akademie der W. IICl. XI Bd. II Abth. München I873.

In this paper a very full account is given of the brain of a case of true microcephalic idiocy. It is beautifully illustrated. He concludes that as the microcephalic brain shows no resemblance to the ape brain, nor to the brain of the human foetus at any period of its development, it cannot possibly be an atavistic brain.

Giacomini; I cervelli dei Microcefali, Torino. I890.

This work may be looked upon as forming another of the great landmarks in our knowledge of this condition. He gives a long account of the literature, and bases his results upon the examination of I7 brains. He specially points out that the term microcephaly 'includes a large mass of heterogeneous material, the one common feature of which is a small brain in a small head'. He therefore, insisted upon a proper classification of the different cases recorded, and himself divides all these cases into three groups;-

Group I;- "Where the morbid process is the primary fact; the microencephaly is secondary to the lesions produced. It is always the brain which is primarily and exclusively affected". Thus, in this group, there is a diminution in the size of the brain purely as the result of some pathological lesion which has occurred during its growth, and, therefore, this group must be completely removed from the field of microcephaly proper.

Group II;- This group includes those cases of true micro--cephaly. It is distinguished sharply from the first by the fact that no pathological lesion can be discovered, and comprises brains 'which present certain common morphological features, and a certain more or less easily distinguished uniformity of type'. That no pathological lesion can be discovered in true microcephalic brains has been repeatedly pointed out by many subsequent writers to Giacomini, but that there is a certain common morphological type found in all such brains has not yet been shown, and, is, in fact, the principal object which I have in view in this paper

Group III;- In this group there is a combination of the first two groups, i.e. there is a true microcephaly present, but at a later date, there is superposed upon the top a pathological condition, so that when we come to examine brains which fall into this group we find evidence of both processes.

This classification is accepted by Prof. Cunningham who had quite independently of Giacomini arrived at a similar conclusion. (See Trans. of Roy. Dub. Soc.; 1895, p. 290).

archand;- Beschreibung dreier Mikrocephalen-Gehirne nebst Vorstudien zur Anatomie der Mikrocephalie, Ab. I. Nova Acta der Kais. Leop.-Carol. Deutschen Akademie der Naturforscher, Band liii., No. 3, 1889. Ab. II., Band lv., No. 3., 1890.

This paper is well illustrated, and contains a very full account of the literature up to that date. He attempts to classify microcephalic brains into three groups according to their weight;-

An excessive group- with all brains up to 500 grammes;

A medium group, from 500 grammes to 800 grammes; and

A Slight group from 800 to 1100 grammes.

This classification, however, is a purely arbitrary one, and has never been accepted.

Marchand;- Sitz. der Gesel. zur Beför. der gesammt. Naturw. zu Marbur No. 2. März., 1892.

In this paper a description is given of the brain of a very typical microcephalic idiot, named Georg. Volp. (See later).

Mimgazzini;- Il Cervello in relazione con i Fenomeni Psichici. Biblioteca Anthropol.-Giuridica, Serie I, Vol. xxii. Torino, 1895.

A very good synopsis of this paper will be found in Prof. Cunningham's memoir (Trans. of Roy. Dub. Soc. 1895) He states that in some microcephalic brains characters are found which do not occur in the ordinary development of the individual, but which is presumed to have been present in an ancestral form. This constitutes an atavism, and he discusses the question why such atavisms should arise, and he comes to the conclusion that pathological conditions are the disturbing influences which allow such atavistic characters to reappear. "An atavistic reminiscence is then nothing more than a sign indicating that the evolution of an organ has not been carried out with complete and normal regularity; disease is the condition necessary for the reviving of atavism".

Cunningham and Telford Telford-Smith;- Scient. Trans. of Roy. Dub. Soc. 1895. The Brain of the Microcephalic Idiot. In this paper a most complete examination has been made of the brains of two microphalic idiots, 'Fred' and 'Joe'. The arrangement and grouping of the fissures and convolutions have been most carefully described and a comparisom made with the ape brain on the one hand, and the foetal human brain on the other. As a result of this examination they have pointed out those features which resemble the human foetus and those which resemble the ape , and they have pointed out that the simian characteristics show a curious mixture of those which are typical of a high ape, and those which are typical of a low ape. Finally they have concluded that the condition is an atavism, but they attach to this word a different meaning than that of Vogt. They do not consider that a simple arrest of development in which a transitory condition becomes stereotyped constitutes an atavism. To them something more is required; "it is necessary that certain of those ancestral features which are omitted in the ordinary course of development should be reproduced, or that certain of those parts of the phylogenetic history, which in the ontogeny of the individual have become blurred or abbreviated, should reappear in a distinct and intelligible manner." And, as a result of this they come to the conclusion that the "convolutionary arrangement is more ape-like than human, and it is so consistent in its pattern throughout the whole cerebral surface that we cannot shut our eyes to the possibility that in it we may have a tolerably faithful reproduction of the gyri and sulci which at one time were characteristic of an early stem-form of man".

They consider that to maintain that pathological conditions are the only exciting causes in cases of microcephaly is quite untenable. "As well might we look for pathological cause to explain the occasional reappear-ance of an extra digit in the horse, etc. And, lastly they show that none of the pathological causes mentioned by Mingazzini are present in true microcephalic cases.

Pfleger und Pilcz;- Arbeit. aus dem Inst. f. Anat. und Physiol. Wien. V. Ht. I897.

In this paper several microcephalic brains are described, most of which however, exhibit various pathological conditions. They consider that there is a group of cases in which the usual pathological causes are absent, i.e. corresponding to group II of Giacomini. In group I he places these cases where a gross pathological lesion is present such as porencephaly, atrophy, hydrocephalus etc. but he considers that those cases which he places in group II are also due to a pathological cause which is of a different nature than the others, and he suggests probably the condition is due to a "periencephalitis" which causes an arrest of development. No attempt is made to explain in what manner or from what cause this "periencephalitis" is due, and the view that the condition is an atavism is not discussed.

A very full account of the literature up to date is given.

ingazzini;- Beitrag zum klinisch-anatomischen Studium der Mikrocephalie Monats. Psych. u. Neur. I900. p. 429.

In this paper a very full description is given both of the brain and of the medulla and cord of a twelve year old child. He concludes by reasserting his view that the condition is due to an atavism, and that such is produced by a pathological cause which results in the arrest of the normal development.

In regard to the view of Prof. Cunningham that the condition is an early stem form, he says;- "Mir scheint es nun, dass diese Rückkehr zu den veralteten Begriffen Vogt's, die später von ihm selbst verworfen wurden, sich nicht auf entscheidende Beweisgründe stützt; es ist eine reine Hypothese, zu deren Annahme uns der Mangel an vergleichbaren Elementen sehr wenig ermutigt. Aber ebenso unbegründet scheint mir die Meinung derjenigen, welche unter dem Einfluss der neueren bio-mechan--ischen Lehren Bildungen, die in embryonalen oder pithekoiden Zuständen ihr vollkommenstes Vorbild finden, rein mechanischen erklären wollen".

He gives a very complete account of the literature up to date.

MacNamara and Burne ;- Jour. of Anat. and Physiol. Vol. , 1903, p. 258. Here a very short account is given of the brain of a true microcephalic idiot. It is of special interest owing to the extraordinary close relation which it presents to the brain of as described by Prof. Cunningham. This resemblance is so close that it is stated that the description of the one brain would apply equally well for the other. It is this brain which is now in the Museum of the College of Surgeons of England.

Description of the Brain

of

ROBERT LINDSAY.

(The microcephalic idiot).

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1. Weight of Brain

The brain of Robert Lindsay on removal from the skull weighed 325 grammes. A comparison between this brain and other well-known microcephalic brains will be found in the following table :-

Robert Lindsay	21 years	325 grammes
Male described by Joseph	22 "	351 "
Female described by Van Schouwen	22 "	345 "
The Jena Microcephale	26 "	305 "
'Fred'	29 "	352 "
'Joe'	60 "	559 "
Female - Gore and Marshall	42 "	283 "
Normal adult human brain		1360 "

The above result is very interesting as it shows a very close relation between the weight of Robert Lindsay and that of two other microcephales of approximately the same age, while it is almost ~~of exactly~~ the same weight as the brain of Fred, who was eight years older. It is a small microcephalic brain when compared with those given by Marchand in his list, but not by any means the smallest, since the brain described by Gore and Marshall is considerably smaller.

The relation of the brain weight to the body weight is shown in the following table :-

Robert Lindsay	1 :
Fred	1 : 110
Joe	1 : 109
Normal	1 : 31

Weight of Mesencephalon, Cerebellum, Pons and Medulla

In the case of Robert Lindsay these weighed :

Weight of Cerebrum	247 grammes
Weight of Mesencephalon etc.	88 "
Weight of brain	335

If we regard the weight of the cerebrum as 100, the cerebellar weight of Robert Lindsay would be 26·3 . To understand the significance of this I have recorded in the following table the percentage weight of the cerebellum, etc., in various animals :-

	% weight of cerebellum, etc.
Robert Lindsay,	26·3
Fred ;	32.5
Joe,	29.3
Chimpanzee (Cunningham)	23.4
" (Bischoff)	21.0
Orang (Cunningham)	18.5
" (Wagner)	20.0
Gibbon (Bischoff)	25.0
Normal brain (Cunningham)	15.0

These results show that the percentage weight in the microcephale differs very greatly from the normal. In fact, it is double, and it is also greater than that of any of the anthropoid apes, a point of great interest since, on considering the various theories of this condition, we might have expected a far closer relationship than the above.

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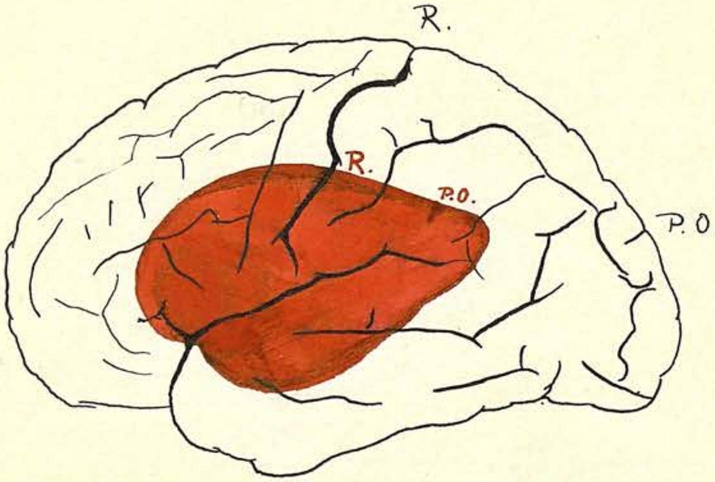
3. Cerebrum

(a) General Shape :

The microcephalic cerebrum is greatly reduced in size, but its different parts have not all suffered equally. Cunningham has pointed out that the greatest diminution has taken place in the parietal and occipital lobes, so that the cerebellum is only partially covered. This diminution is, however, really greater than even Cunningham has imagined, since by making a comparative study of his two brains (Fred and Joe) with other microcephalic brains, we are in a position to identify the various sulci more accurately now than was possible then, and there is considerable evidence pointing to the fact that the praecentral fissure has been mistaken for the fissure of Rolando, (this I shall discuss fully later), and therefore, as the fissure of Rolando lies behind the praecentral fissure, the parietal and occipital regions are even more reduced than Cunningham has pointed out, and the frontal lobe, in consequence, assumes a quite spurious preponderance.

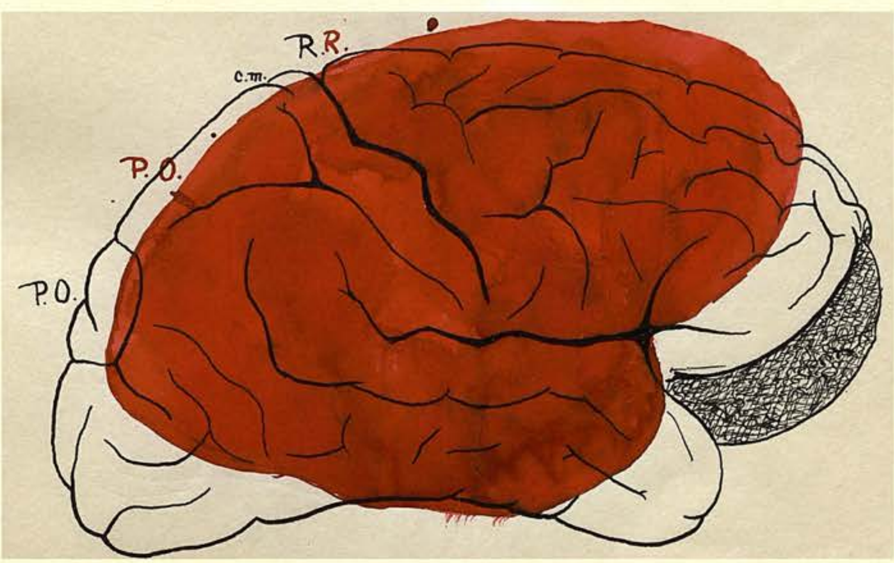
In order to compare the size of the brain of Robert Lindsay, with a typical normal brain, I have superposed the one upon the other in the following figure.



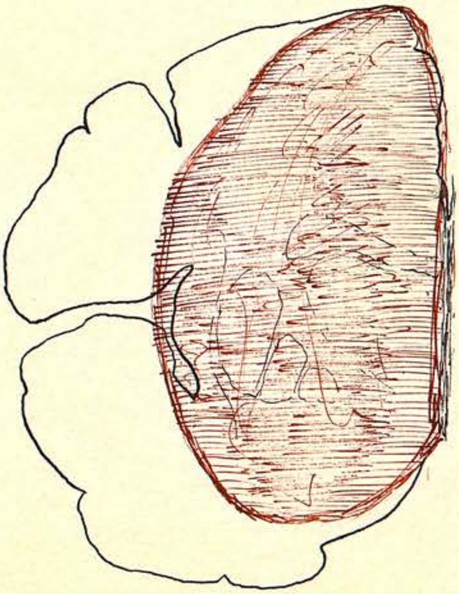
Both brains reduced ½.

The normal brain (in black) is the one which is figured in Cunningham's Text-book of Anatomy on page 5I4. I first of all measured the antero-posterior length of a brain which I obtained from the post-mortem room of the Royal Infirmary from a body of very nearly the same age as Robert Lindsay. I then drew on the top of this (in red) to scale the brain of Robert Lindsay, so that these two brains may be directly compared with one another. In this manner we are able to see at a glance the great differ--ence in size between the two brains. It will also be noticed that the outline of the microcephalic brain is rather different from the normal, especially towards the occipital pole, which is greatly reduced in size, and is more sharply pointed. The full nature of these changes will be seen on the following page.

These changes are also to be found in the brain of Robert Lindsay, and in order to demonstrate them clearly I have superposed a tracing of the right hemisphere of Robert Lindsay upon the right hemisphere of a normal human brain. I first traced exactly the normal human adult brain figured by Cunningham on p. 514 of his "Text-Book of Anatomy". I then took a photograph of the right hemisphere of Robert Lindsay and enlarged it until it was of the same magnification as the above, and then I superposed the microcephalic (in red) upon the normal (in black), and by comparing these two outlines I was enabled to realise the principal differences between the two brains. In superposing the one brain upon the other, I applied the upper end of the fissure of Rolando of the one to the corresponding point in the other, and the Sylvian point of the one to the Sylvian point of the other.



From this figure it is at once apparent that in Robert Lindsay the parietal and occipital areas have become more diminished than the frontal and temporal areas. Of these latter, the temporal area has suffered rather more than the frontal. But the point which is most noticeable is the great reduction of the occipital region. This is, undoubtedly, due to the great reduction in the occipital region itself, but also to the reduction in the parietal region and consequent drawing forwards of the occipital region. As a result the posterior part of the brain assumes a triangular outline, which is rather characteristic of the microcephalic brain. The full significance of these changes is shown in the accompanying figure. It is very clearly demonstrated that the microcephalic brain is most reduced in thickness. (The outline of the brain of Robert Lindsay was taken by viewing the brain from the posterior end, so that the maximum curve was obtained, and this was enlarged until the mesial aspect of the two brains coincided.)



Therefore, as a result of a general superficial examination of the brain of Robert Lindsay, the following points may be determined;-

I. Brain + pia mater (fresh). = 335 grammes.

I.	Brain + pia mater (fresh).	=	335 grammes.
	Cerebellum, pons, etc.	=	88 " .
	Hemispheres	=	247 " .

2. The brain is greatly reduced in size, and certain areas have suffered more than others. The chief change is the diminution of the occipital pole, so that this part of the brain is triangular in outline. The reduction is due to a primary reduction in the occipital region; but it is also due to a primary diminution in size of the parietal region, shown by the displacement forwards of the ext. parieto-occipital fissure. The temporal region is also reduced, chiefly in the region of the 'temporal pole'. The frontal lobe is least affected as regards reduction in size.

I shall now proceed to take up and describe the various fissures in turn.

Description

of the

Convolutions and Fissures

on the surface of the

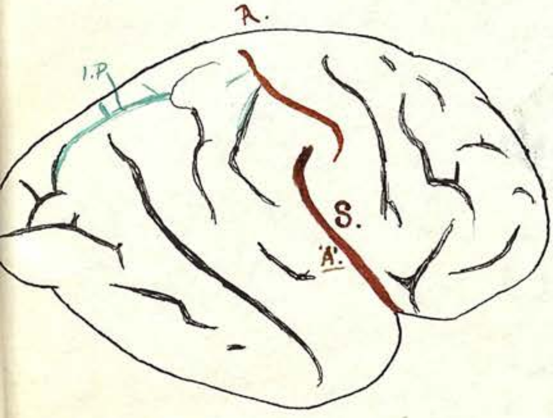
brain

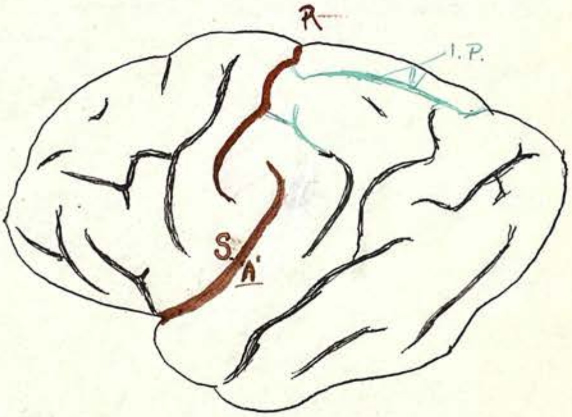
of

Robert Lindsay.

SYLVIAN REGION.

The Sylvian fissure is alone represented by the stem and the posterior horizontal limb. The stem exhibits the usual relations on the base of the brain. The posterior ramus is short and upright, and bends suddenly forward at its termination.





It measures 47 mm. long on the right side, and 46 mm. on the left. The Sylvian angle on both sides is reduced. On measuring it by the method described by Prof. Cunningham on p. 302, i.e. it cuts a perpendicular at right angles to the long axis of the hemisphere at an angle of 45° on the right side, and at an angle of 48° on the left. Cunningham states (p. 303) "this reduction in the Sylvian angle is both a foetal and a simian character" The following table gives a comparison with the Sylvian angle in other microcephalic brains and also with those of the adult, foetal and ape brain;-

	Right Side.	Left Side.
Robert Lindsay.	45°	48°.
Fred.	46°.	60°.
Joe.	50°.	56°.
Normal adult brain.	66°.	70°.

Eight-month foetus.	57°.	64°.
Chimpanzee.	52°.	56°.
Cynocephalus.	48°.	49°.

In the case of Robert Lindsay, it will be noted that the reduction in the Sylvian angle is very considerable, being less than the eight months foetus and nearer that of the lower ape; but, it must not be considered that because the Sylvian angle in the microcephalic idiot approaches closely to the lower ape type, that it is necessary ia a reversion to the ape type; and although the Sylvian angle is also reduced in the foetal brain, it does not necessarily follow that its reduction in the microcephalic brain is simply a persistence of a foetal characteristic. I shall discuss the full significance of this reduction in the Sylvian angle later when I consider the comparative morphology of the typical true microcephalic brains on record, and shall then try to show that this reduction is really the result of a mechanical disturbance which has affected the brain during its early development, and thus is neither a foetal nor a simian characteristic.

The opercula covering the island of Reil are very poorly developed. If the Sylvian fissure be opened up, it will be seen that the temporal and fronto-parietal opercula scarcely overlap the island of Reil at all. The fronto-parietal operculum extends outwards perpendicularly outwards from the submerged insular area, i.e. there is no true operculum present. The downward growth of that part of the frontal lobe, which normally comes to overlap the insula has not taken place, and thus the fronto-parietal operculum, as an operculum, has not developed in either hemisphere.

The temporal operculum is only slightly developed. If the fissure of Sylvius be opened up, it will be found that there is only a slight overlapping part of the temporal region, most marked anteriorly. As we pass backwards towards the termination of the posterior ramus, the overlapping area becomes less and less, and at the posterior extremity of the fissure it has completely disappeared. Even at the anterior part, however, the actual amount of overlapping is very small, being only 2 mm. at its most marked point, so that the temporal operculum as an operculum is only feebly developed. In both hemispheres about the middle of the posterior ramus (at the point I have marked 'A') there is a slight localised growth of the gray matter forming a buttress, which has caused a corresponding slight hollow in the fronto-parietal area. The posterior ramus is also characterised by another feature; it is unusually deep measuring mms. On opening it it would appear that owing to the reduced angle of Sylvius the opercula were unable to obtain sufficient room for their proper development, and had instead, pushed the floor of the fissure of Sylvius inwards. As I shall shortly afterwards describe, the island of Reil is very greatly reduced in size, and therefore the opercula which cover it externally will be small, and if these opercula should be larger than the island of Reil, the extra development will tend to deepen the fissure. In this case I shall show later, that the fibres arising from these two opercula are extremely poorly medulated, showing that the opercula are not completely developed. It is also interesting to note that the temporal operculum tends to slope upwards, i.e. if a slip of paper be inserted into the posterior ramus of the Sylvian fissure

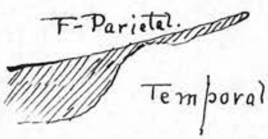
it will pass slightly downwards and inwards.
The absence of the fronto-parietal operculum, and the extremely poor development of the temporal operculum are points of great interest, since it shows that the change which has occured at some period in the development of the microcephalic brain must have taken place before that period at which the fronto-parietal operculum developes in the human foetus, which is given by Cunningham (p. 82) as "the latter half of the fifth month".
He also states (p. 304)- "The temporal operculum appears first, and soon after it the fronto-parietal operculum begins to grow. In the first instance the temporal operculum is more energetic in its growth than the fronto-parietal operculum, and it consequently happens that in the sixth month when the opercula meet, and close in the hinder half of the Sylvian area, there is more of that district covered by the temporal than by the fronto-parietal operculum. This condition is only apparent during the early stages of the Sylvian development. Before long the fronto-parietal operculum takes the more prominent share in the submergence of the insula, and this excess of growth-energy, carried on through infancy and early childhood, leads to the depression of the posterior horizontal limb of the Sylvian fissure, and to a consequent increase of the Sylvian angle.

In the brain of Fred only the temporal operculum has developed. Its upward growth has been in no way opposed by the downward growth of the fronto-parietal operculum, and the result is a great reduction of the Sylvian angle, or, in other words, a very upright condition of the Sylvian fissure."

It is very interesting to compare the opercula in Robert Lindsay with those in the brains of Fred and Joe. The condition is identically the same in all three; the temporal operculum is only slightly devel--oped, and the fronto-parietal boundary is in the form of a high wall, from which no overlapping process proceeds.

Cunningham suggests that the condition of the opercula may be responsible for the upright condition of the Sylvian fissure, but it appears to me to be more probable that the upright Sylvian fissure is the primary factor, and the condition of the opercula secondary to this; or, the same cause which has produced the upright Sylvian fissure has also produced the deficiency in the growth of the fronto-parietal and temporal opercula. The essential feature is the upright Sylvian fissure; the Sylvian fissure has assumed this position before the development of these two opercula, i.e. some time before the fifth month, and as a result of this position the cortex surrounding it has been subjected to mechanical disturbances which have interfered with its normal growth and development. There is one special point to which I wish to draw attention, and this is that on the right hemisphere of Robert Lindsay the fissure of Rolando and the fissure of Sylvius are in the same straight line. (See fig. and also plate). On the left hemisphere the fissure of Rolando and the fissure of Sylvius lie parallel to one another. (See Fig.). These two points are of great importance, especially the first, and, as far as I am aware, have been completely overlooked by all previous writers on this subject. I do not propose to discuss their full sig--nificance at this stage, but shall do so later when I will discuss the various positions which these two fissures may assume in regard to each other, after which we are in a better position to clearly understand what has been the cause at work, and in what manner it has produced this result.

The submerged part of the insula is small, narrow and smooth. When the two lips of the Sylvian fissure are opened up, the first point to attract attention is the depth of the fissure, (15 mm). Then the absence of the fronto-parietal operculum and the exceedingly feeble temporal operculum are noticed, and lastly the small extent of the insula is at once forced upon the attention. If we were to make a tracing of the outline of the insula in this case it would appear as I have shown in the following figure; it is a long, thin, smooth, triangular field, without any sulci or gyri upon its surface. The chief part of the insula, however, is upon the surface in front of the Sylvian fissure, and this I shall discuss later in connection with the fronto-orbital sulcus.



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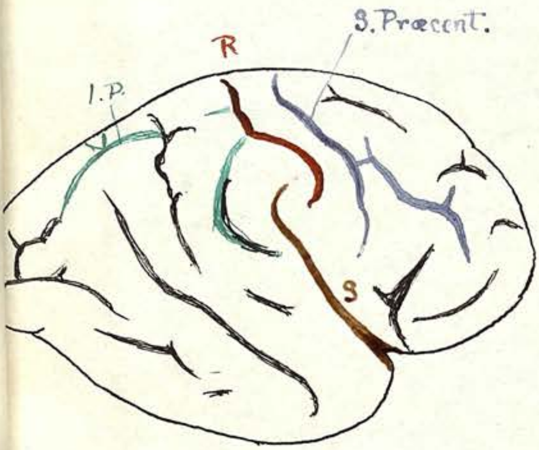
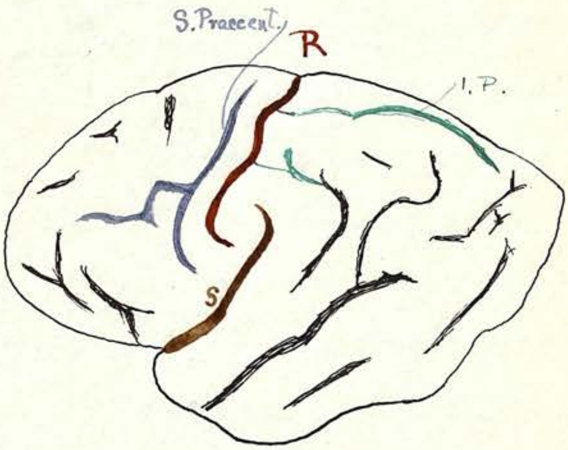
The Fissure of Rolando.

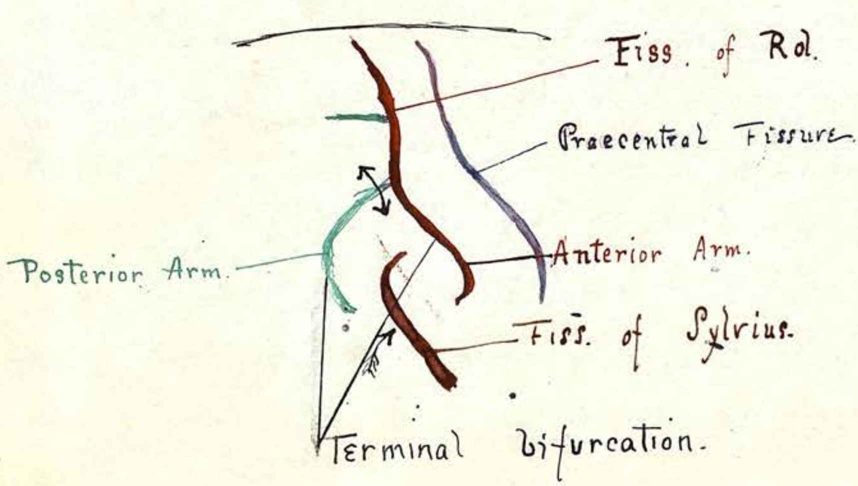
The correct recognition of this fissure in the microcephalic brain is of very great importance, since in the greater number of microcephalic brains it has been mistaken for either the praecentral or postcentral fissures, thus causing great confusion in the correct naming of the surrounding fissures and giving a quite erroneous idea of the relative size of the frontal, parietal and other lobes. And as I shall afterwards show, the most important changes in the microcephalic brain have occured in relation to the fissure of Rolando.

In the brain of Robert Lindsay, the fissure of Rolando can be recognised clearly beyond all doubt. It is the fissure which I have marked in red in the following two figures.





The praecentral fissure is also clearly that fissure lying immediately in front of it, which I have marked in light blue. So that, in this brain we can determine the fissure of Rolando beyond all doubt. In both hemispheres it is formed upon a some- -what similar plan. It is a short furrow, slightly curved, and of no great depth. In the right hemisphere, it begins just at the superomesial border of the hemisphere, and passes downwards and forwards for 47 mm, ending just anterior to the termination of the posterior ramus of the Sylvian fissure. where it suddenly turns backwards. The superior and inferior genu are absent, but there is a slight curve forwards at the junction of the middle and lower third of the fissure. On opening the fissure it is found to be of no great depth,   mms. and to present no indication whatever of any sign of a deep gyrus or buttress. The two walls are smooth and closely applied to one another. There is a very important feature on the posterior wall of the fissure, namely;- a little below its upper third a small fissure passes out from it and runs transversely backwards for a distance of 8 mm; and, the lower extremity of the fissure ends in a terminal bifurcation (See fig.) giving the appearance of an inverted Y. The posterior arm of the bifurcation is well marked, and unites with the fissure of Rolando just at the point where the slight forward curve is found, i.e. at the junction of its middle and lower thirds. The fissure is more or less straight until this point, and then the fissure of Sylvius has apparently rotated forwards and pushed the lower third of the Rolandic fissure forwards also, and, then this posterior arm has united with the fissure just at the point of the bend.



What is the true nature of this posterior arm I shall discuss later, but, if it is examined closely in this right hemisphere it will be found to be separated from the fissure of Rolando by a gyrus which is only slightly depressed below the surface. This latter point is important in both Fred and Joe this terminal bifurcation of the Rolandic fissure is present, but there is no deep gyrus separating the posterior arm from the true fissure of Rolando.

The fissure of Rolando on the left hemisphere is slightly different from the right. It begins at the supero-mesial border of the hemisphere just in front of the calloso-marginal fissure. It extends downwards and forwards for 50 mm. and ends just in front of the posterior ramus of the fissure of Sylvius in a manner exactly similar to that found on the opposite hemisphere. There are two slight curves present, , one at the junction of the upper and middle thirds, and the other at the junction of the lower and middle thirds. On opening the fissure, it will be found to be shallow, 14 mm. deep, to present no deep gyrus or buttresses, and to be bounded by smooth walls. It presents the same two fissures passing backwards from its posterior wall, neither of which, however, being so well marked as in the right hemisphere. The upper of these two fissures arises just above the lower part of the upper third; it is shallow and passes directly backwards to unite with the intra-parietal sulcus. The lower, which corresponds to the terminal bifurcation in the opposite hemisphere, is separated from the fissure of Rolando by a superficial well-marked gyrus across which there runs a very slight fissure connecting this separated posterior arm with the fissure of Rolando.

The angle which the fissure of Rolando forms with the mesial border of the hemisphere on the right side is 60°, and on the left 60°.

In neither hemisphere does the fissure of Rolando pass into the fissure of Sylvius, and there is no inferior transverse furrow present, neither is there any deep gyrus towards the lower end of the fissure of Rolando, suggesting that the inferior transverse furrow was present, but had united with the lower end of the fissure of Rolando.

In discussing the significence of these appearances of the Rolandic fissure, I cannot but do better than refer to page 3II of Cunningham's paper on the microcephalic idiot brain. He refers specially to two points;-

First;- "It exhibits simian characters of the greatest interest, and these characters assimilate more nearly those of the corresponding furrow in a low ape than those of the fissure of Rolando in an anthropoid ape. Thus the walls are smooth and even, and present no trace of the interlocking gyri which are so prominent a feature of the normal human brain, and also to a less extent of the brain of a chimpanzee and an orang. Further, there is not the slightest evidence which would lead to the conclusion that the sulcus had been developed by the fusion of two originally distinct pieces. As in the low ape it presents an equal depth throughout, and there is not a trace of the deep annectant gyrus, or the shallowing, which possesses so high an importance in the normal human brain, and also, as a rule, in the anthropoid brain".

Second;-"But perhaps the most significant feature of all is the fact that the fissure of Rolando in three out of the four microcephalic cerebral hemispheres is distinctly shallower than the intra-parietal furrow. In the cebus, macaque, and baboon, and in all low apes we have had an opportunity of studying, this condition constitutes a characteristic feature of the cerebrum; indeed, in many cases the intra-parietal sulcus will be found in the low ape to be nearly twice as deep as the fissure of Rolando. The latter furrow is, comparatively speaking, shallow. In the chimpanzee and the orang the difference in depth between the fissure of Rolando and the intra-parietal sulcus is not nearly so marked as in the low ape, but still it is manifest that the latter is the deeper of the two. In the normal human brain exactly the opposite condition holds good. The greater depth of the fissure of Rolando, and the greater firmness with which it is stamped upon the surface of the cerebrum, are essentially human characteristics"...."But the difference in relative depth of the fissure of Rolando and the intra-parietal sulcus in man and in the ape assumes a still greater importance when we bear in mind that there is a very general consensus of opinion in favour of the law first enunciated by Pansch, that it is possible to estimate the relative period of development of a furrow by comparing its depth with that of other sulci. In other words, according to this law, the deepest furrows in the adult brain are those which first make their appearance upon the surface of the foetal brain. If this be true, and it must be admitted that all we know of the development of the cerebral cortex would seem to indicate that in the great majority of cases it is so, the relative morphological value of the fissure of Rolando and the intra-parietal sulcus is different in man and the ape; and further, it becomes evident that as we descend in the primate group the importance of the fissure of Rolando diminishes, whilst the value of the intra-parietal sulcus increases.

" This view receives important corroboration from a study of the evolution of these two furrows. All the evidence at our disposal points in the clearest manner to the intraparietal sulcus as a furrow which possesses a greater phylogenetic antiquity than the fissure of Rolando. Thus it is developed in brains (Lemur nigrifrons, Hapale pennicillata) in which there is not a trace of the fissure of Rolando. In the human brain therefore, we have an exceedingly interesting instance of a want of development of the two fissures in question, and the simian tendencies which we have indicated in the microcephalic brains exhibited in the fissure of Rolando, assume a real importance and significance."

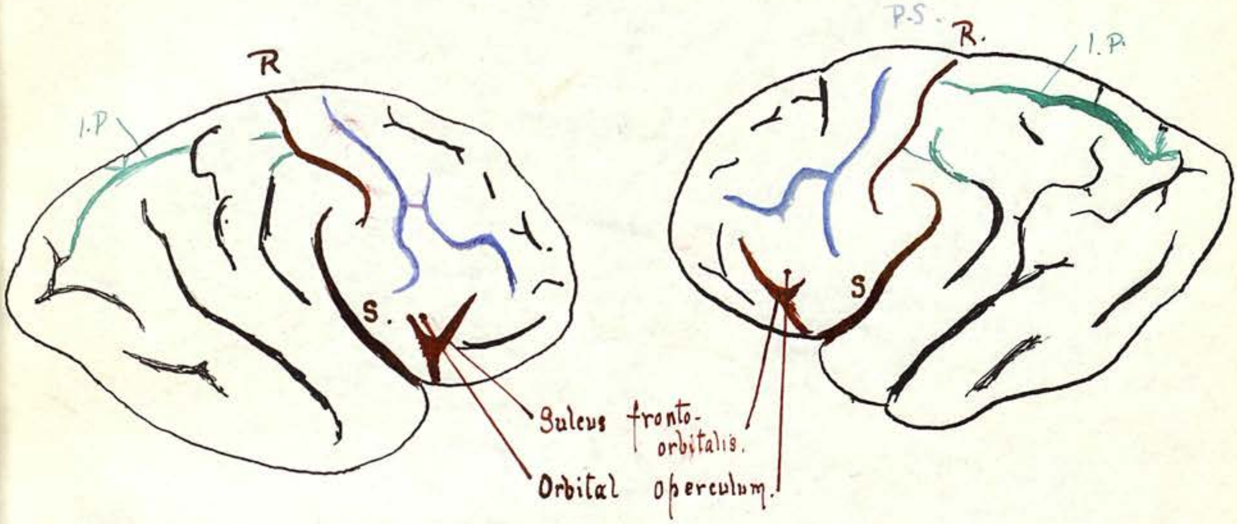
This two statements of Prof. Cunningham's in regard to the brains of Fred and Joe are equally applicable to the brain of Robert Lindsay. It posseses a short, shallow fissure of Rolando with smooth bounding walls, and without any trace of a ddep annectant gyrus; and it is distinctly shallower than the intra-parietal sulcus. This is shown in the following table;-

	Right Side.	Left Side.
Fissure of Rolando.	12 m/m.	14 m/m.
Intra-parietal Sulcus.	14 m/m	15 m/m

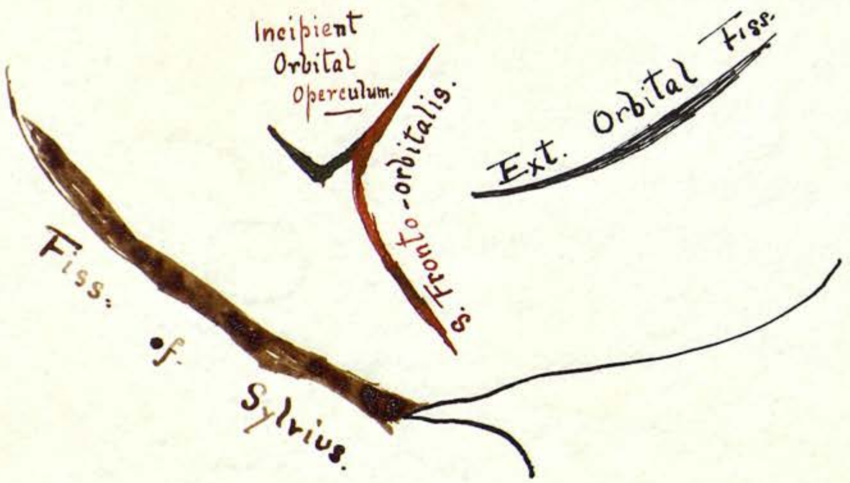
I do not propose to discuss the fissure of Rolando in further detail at present. I have shown that it exhibits most marked simian characteristics, as has already been pointed out by Prof. Cunningham. There are several other points, however, of the greatest importance in connection with this fissure, which I shall take up in full later, after I have shown the different varieties which this fissure may undergo in other microcephalic brains, and once we have understood this, we are then in a position to realise the true significance of these changes.

The fronto-orbital sulcus.

The fronto-orbital sulcus is very well marked on both hemispheres of Robert Lindsay. It cuts sharply into the substance of the brain, and consists of two arms of about equal length, and in the form of a V. (See fig.).



From this figure it will be seen that the sulcus begins just in front of the stem of the Sylvian fissure, and ascends vertically for a distance of 20 mms. It cuts the superciliary border of the hemisphere and then turns forwards at an angle of I20° and passes forwards into the frontal lobe for a distance of 10 mms. The above description is suitable for either hemisphere, the fissure being identically the same on both sides. This brain is specially interesting, however, owing to the fact that there is an incipient orbital operculum. In both hemispheres there has been a localised growth of the gray matter just behind the sulcus, bounded inferiorly by a V-shaped fissure. This growth is clearly an orbital operculum, and shows very clearly that the fronto-orbital sulcus is comparable to the anterior horizontal ramus of the human brain, and not to the ascending ramus, while that part of the fissure limiting the orbital operculum inferiorly, which I have marked in red in the following figure is the ramus ascendens of the human adult brain.



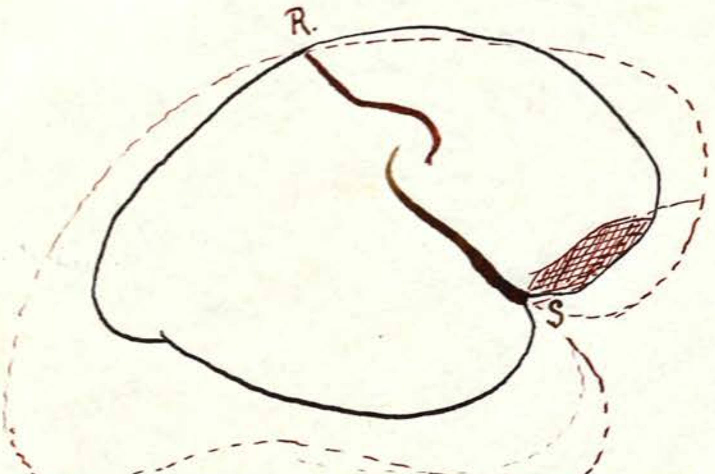
The insula in the brain of Robert Lindsay may be summarised as follows;- it consists of a posterior submerged part and an anterior exposed part.

The <u>submerged</u> part is seen on separating the lips of the posterior ramus of the Sylvian fissure. It is a smooth, narrow, small triangular area, covered mostly by the sloping wall of the temporal operculum, and bounded superiorly by the perpendicular wall of the fronto-parietal operculum. The <u>exposed</u> part lies in front of the fissure of Sylvius and is bounded anteriorly by a deep sulcus "in all respects identically the same as the sulcus fronto-orbitalis". There is an incipient orbital operculum present.

The reason of the non-development of the fronto-parietal and temporal opercula, I shall discuss later; suffice it to say at present that it is not an ape characteristic, since both these two opercula are present even in the lower apes. The presence of such a very well marked fronto-orbital sulcus is an ape characteristic of the very highest importance, because it is not a sulcus which is found at any period in the embryonic brain. It is thus not a foetal characteristic, and can only be regarded as a direct transition to the ape condition. It is a feature which is constant on all microcephalic brains (See Cunningham, p. 307) and, to quote Cunningham, "is one of the most striking, and at the same time one of the most common features in an extreme case of typical microcephalis brain".

The Frontal Lobe.

In this brain it is possible to sharply define the frontal lobe, since there exists no confusion about the correct recognition of the fissure of Rolando. The first fact to which attention is drawn on examining this region, is that the frontal lobe is reduced is size, both from above downwards and from side to side. I have superscribed a tracing of this brain upon a typical adult human brain reduced to the same size; and it will be noticed that the microcephalic brain has a rather differently shaped frontal lobe; the supero-mesial border slopes downwards more quickly and the anterior margin is sharper, (beak-like), while the superciliary margin tends to slope upwards. The convexity of the brain is also greatly reduced, especially in the region of the superior frontal convolution.



The superciliary border is poorly marked and the ezternal orbital sulcus is situated just in this position.

The sulci which are present are the same in both hemispheres but as they are differently arranged I shall consider each separately;- They are as follows;

The Sulcus-orbitalis,

The Sulcus praecentralis superior,

The Sulcus fronto-orbitalis,

The Sulcus praecentralis superior,

The sulcus praecentralis inferior,

The sulcus frontalis superior,

The sulcus frontalis inferior, and

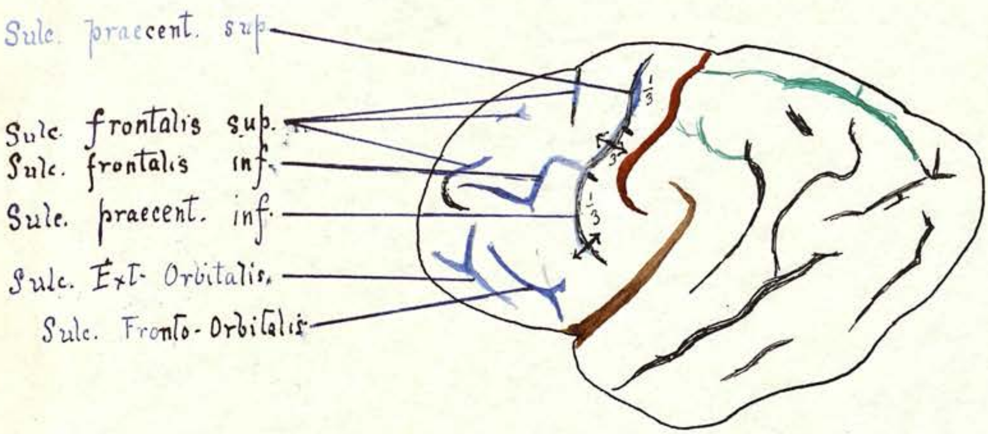
(The external orbital sulcus).

There is no traces of a sulcus frontalis medius, nor of a sulcus frontalis paramedialis.

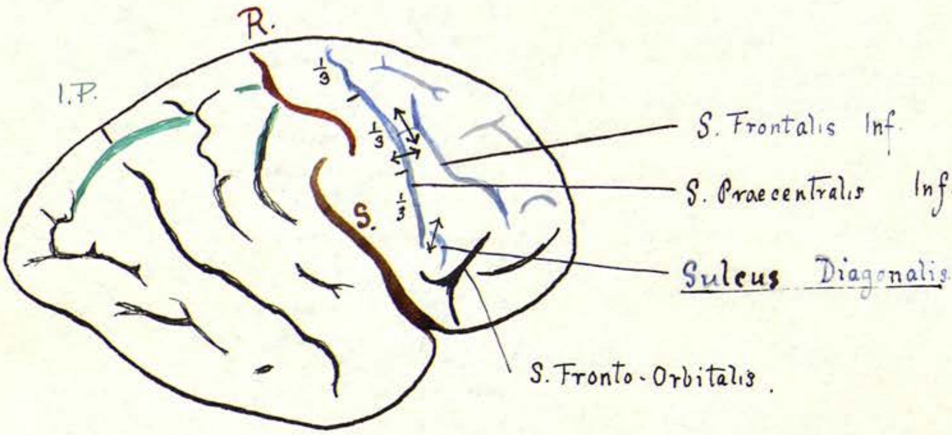
I. The <u>fronto-orbital</u> sulcus has already been described separately.

2. The <u>sulcus praecentralis superior and inferior.</u>

These two sulci are united together to form one sulcus in both hemispheres of Robert Lindsay. They are at once easily recognised lying in front of the fissure of Rolando, and separated from it by a narrow ascending frontal convolution.



In both hemispheres it begins about one cm. from the supero-mesial border, and passes downwards and forwards to end about one centimetre above the middle of the posterior ramus of the Sylvian fissure. In both cases it exhibits three curves, an upper antero-convex, a middle antero-concave, and a lower antero-convex curve. In the left hemisphere they are all of very nearly the same length, the lower being rather the longer. In the right hemisphere, however, the upper two curves occupy the upper third of the praecentral fissure, while the lower convex forwards curve occupies the lower two-thirds of the fissure. This fissure is not of the same depth throughout its whole length. The lower convex forwards curve is deep, the upper two/thirds, (or half) is shallow. At the point of junction there is a very slight deep gyrus visible on opening the fissure widely. (See ↔ in fig.)



And if we now come and examine the lower end of this praecentral fissure, (See fig. and also plate at end of paper) it will be noticed that on the right hemisphere there is a slight fissure just in front of the lower end of the praecentral fissure, but not directly united to it. In the left hemisphere, however, it is united and continuous with the lower end of the praecentral fissure (See fig.), and on opening this lower part it will be found that there is a deep but well marked gyrus (just where I have placed the arrow), so that we have the same condition present in both hemispheres only in the one this small fissure is united to the praecentral fissure, while in the other it is separated. This fissure is very small and of very little importance, and probably represents the sulcus diagonalis of Eberstaller. (See Cunningham, p. IOI); it is placed too far forward to be the inferior transverse fissure.

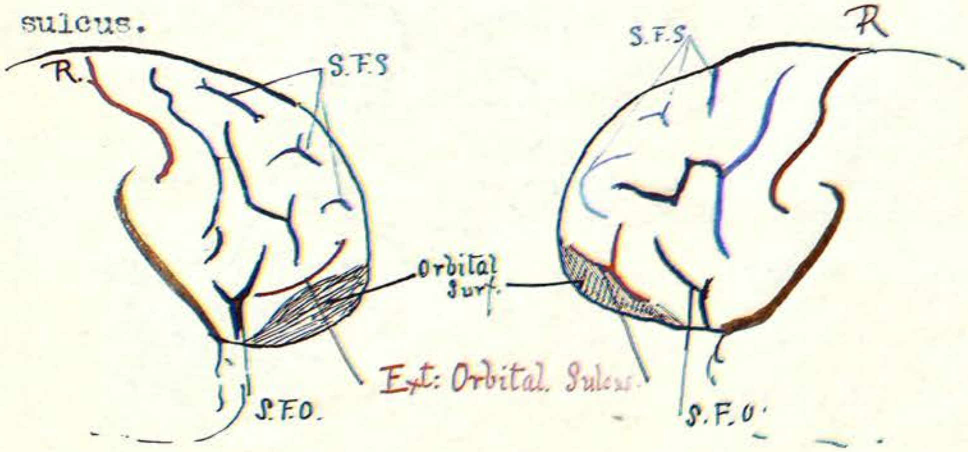
The long sulcus which is found in front of the fissure of Rolando thus represents the combined superior and inferior praecentral sulci. Opposite the middle point of this long sulcus, a horizontal ramus extends forwards into the frontal lobe; this is the inferior frontal sulcus.

The inferior frontal sulcus is well marked on both hemispheres. It is a long, deep and curved fissure. In the left hemisphere it is directly continuous with the praecentral fissure, no deep gyrus being present at the point of junction. It does not unite with the praecentral fissure at the point where the superior and inferior praecentral sulci become confluent, as show shown by the sudden shallowing of the fissure; it arises about 5mms. below this point. In the right hemisphere the inferior frontal sulcus does not unite with the praecentral sulcus; it is separated from it by a distance of about 5 mms. across which a shallow groove runs thus serving to connect the two fissures, but obviously not being part of either. (See Fig.). The course of the inferior frontal sulcus is best seen by examining the above figure; it first runs forwards for 25mms.; then it bends sharply at right angles and passes downwards for 10mms.; and then again sharply bending at right angles it passes forwards for 15mms. It is not of equal depth throughout its whole course. The third part is considerably deeper than the other two.

In the left hemisphere the inferior frontal fissure is also divided into three parts, of which the first is 10mms. long, the second 10mms. and the third 20 mms. It is of equal depth throughout all its course.

The superior frontal sulcus is present on both hemispheres in the form of three separate fissures, sharply marked off from each other. It is thus an interrupted furrow. Of these three furrows the first is the longer, and is almost parallel to the supero-mesial border. The other two are more nearly at right angles to this border. In the left hemisphere the reverse condition is found. The first of the three furrows is at right angles to the long axis of the hemispheres and cuts the supero-mesial border sharply. The other two are more or less parallel to the long axis of the hemisphere; the middle however, is more of the nature of a stellate depression in the surface rather than a fissure. The most anterior is a C-shaped fissure, which curves round the end of the inferior frontal sulcus.

The external orbital fissure in both hemispheres is found just on the frontal side of the superciliary border. On the right hemisphere it is in the form of a long slightly curved fissure, while in the left hemisphere it is T-shaped, the stem running backwards and upwards towards the inferior frontal sulcus.



The ascending frontal convolution stands out very clearly on both hemispheres as a long, narrow gyrus. The slight width between the fissure of Rolando behind and the prae-central fissure in front suggests at once that the motor area must be very considerably reduced in size, and when I later come to discuss the motor strands in the lower brain and cord, I shall point out how very much the pyramidal tracts are reduced in size.

The superior frontal gyrus is narrow and not separated from the middle frontal gyrus. In the left hemisphere it is divided into two by the deep first part of the superior frontal sulcus (see Fig.). There is absolutely no trace whatever of any paramedial sulci. The middle frontal gyrus is also poorly developed, being about the same breadth as the superior. There is also no trace on either hemisphere of a sulcus frontalis medius. The inferior frontal convolution has already been described; the presence of the fronto-orbital sulcus and the conparative absence of both frontal and orbital opercula forms one of the most simian characteristics of this brain.

The brain of Robert Lindsay exhibits an extremely simple character, and consists of a "curious mixture of ape-like and foetal characters". Cunningham (p.317) in discussing the frontal lobe of Fred and Joe states as follows :- "A study of the development of the frontal sulci in man and an examin-ation of the same furrows throughout the order of Primates render it clear that the inferior praecentral sulcus and the inferior frontal sulcus possess a more marked morphological importance than the others, or, in other words, that these two furrows are more firmly stamped upon the brain surface than the others. It is therefore interesting to note that these are the only two well-marked sulci on the external surface of the frontal lobes of Joe. The frontal sulci which stand next in order in point of morphological value are the superior praecentral and the superior frontal sulci. The last named sulcus exhibits in the foetus the interrupted form of development. It appears in a number of isolated pieces, which ultimately run into each other and form the continuous fissure of the adult. In the ape this furrow remains at the stage which is characteristic of the human foetus. It consists of several ununited pieces which even in the chimpanzee rarely run into each other to form a continuous fissure : in a large number of the lower apes it fails altogether. In the brain of Fred both the superior praecentral and the superior frontal sulcus are present, but they retain their foetal condition, and present in consequence a correspondence with the same furrows in the higher apes.

In neither of the microcephalic brains is the sulcus frontalis medius present. This sulcus is later in its development than the others, and is not represented in any ape brain below that of the anthropoid.

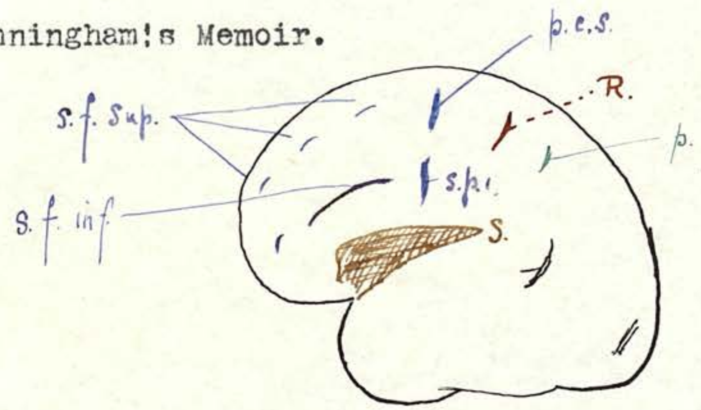
The absence of the paramedial sulcus of the human lobe in the microcephalic brains (Fred and Joe) might have been expected.

In the young human brain it does not as a rule appear until after birth. It is totally absent in the brains of even the highest apes, and also in some of the brains of the lower races of men. As an interesting feature in connection with this, we should not lose sight of the great narrowing and reduction of substance of the first frontal convolution in both the microcephalic brains.

In the brain of Joe the high position of the inferior praecentral sulcus and the close approximation of its horizontal portion to the supero-mesial border of the hemisphere is very striking. This is to be regarded as the retention of a very early foetal condition".

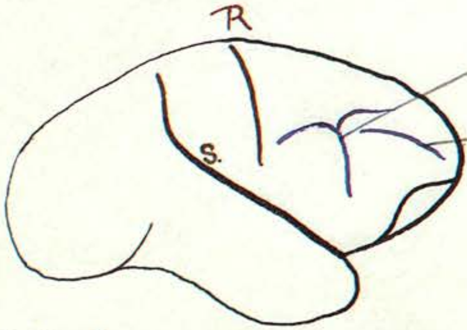
It is quite apparent from this that the combination of simian and foetal characters in the frontal lobe of the microcephalic brain has been specially studied by Professor Cunningham, who considered that it represents an early "stem-form" of the human brain. I have already pointed out (and shall later take up this question in full detail) that a more complete explanation is found of the superposition of a simpler type of brain (similar to that found in the lower apes) upon an already partially developed normal human brain. According to this view the microcephalic brain will not resemble either the simian or the foetal very closely ; it will present features similar to both and also features which are the result of the superposition of the one type upon the other, and as such will resemble neither the simian, nor the foetal nor the adult, but will form a quite distinctive feature of the microcephalic brain. I have pointed out that after I have described the brain of Robert Lindsay completely, I have made a careful complete study of various other typical, true microcephalic brains to determine how many of these features are characteristic of the microcephale, and what variations occur, and therefore I shall defer a closer examination of this subject until later. But at this point I should like to point out how completely it is possible to understand the condition present here on this view - i.e., the superposition of a simple ape-like brain upon a partially developed foetal brain.

I reproduce here a tracing from a foetal brain towards the end of the sixth month from Plate i, Fig. 245 of Professor Conningham's Memoir.



Here it will be seen that the early development of the fissures on the frontal lobe is well advanced. The superior and inferior prae-central sulci are separate, the inferior frontal sulcus is well formed, and the superior frontal sulcus is represented by three small fissures. No other sulci are present.

Let us now examine the brain of a Cebus monkey, (Fig.64, p. 280, Cunningham). Here it will be noticed that the frontal lobe contains only two furrows, the inferior praecentral with its horizontal ramus, and the inferior frontal sulcus. There are no more present.

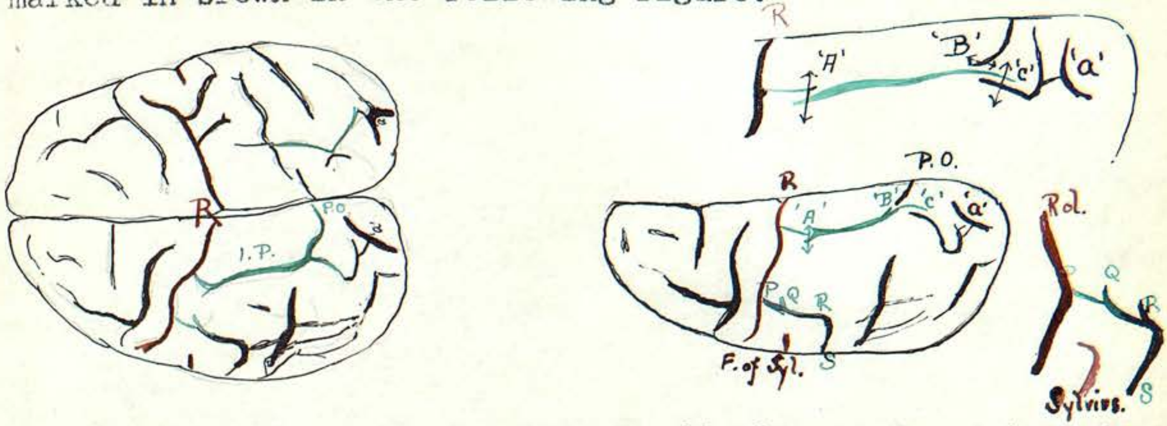


<u>The Parietal Region</u> :

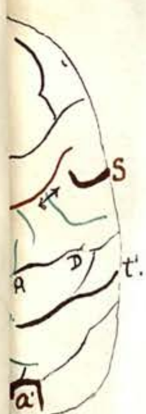
The changes which are found in the parietal region of the microcephalic brain are of extreme importance. They have been overlooked by all writers on this subject, most of whom have based their conclusions upon the investigation of a single case, which is quite insufficient as a foundation for far-reaching deductions as to the nature of the change which has occurred and of its cause. This, as I have already stated, can only be reached by an examination of a large number of microcephalic brains, and therefore I shall leave the proof of the explanation with which I shall conclude the account of this region until later.

The parietal region in the brain of Robert Lindsay is at first sight difficult to understand clearly. It presents a condition which does not resemble either the foetal or the adult human brain, but is more closely allied to the condition found in the lower ape. And just as I have shown that, in the frontal region and other parts which I have already discussed, great changes and deviation from the normal course of development are found, so also similar changes have occurred in the other regions, and thus the parietal, occipital, temporal regions, etc., are also affected. When I come to discuss the occipital region, where the condition in the ape differs so greatly from the condition in man, I shall show that the changes are very great, and as this region is so closely wrapped up with the parietal region, changes in the former must necessarily cause secondary changes in the latter, which will be best understood after we have considered both regions separately. And also the forward rotation of the Sylvian fissure has caused secondary changes in the lower part of the parietal region, and has altered its relation to the temporal region, as I shall describe later. The parietal region is usually described under the heading of "the intra-parietal sulcus", but in this case I have avoided that term, since the changes which have occurred in the parietal region have produced sulci which are not exactly directly included in this term and therefore I prefer to use the term "parietal region".

The condition here is best seen in the left hemisphere, where the arrangement of the sulci is simpler than on the opposite side. The parietal region here is traversed by a single deep fissure, which commences in the fissure of Rolando about the lower part of its upper third, and passes backwards and slightly inwards for a distance of 25 mms, when it unites with the external parieto-occipital fissure, and then passes slightly outwards and backwards for a distance of 10 mms. Superficially it will be seen to pass still further backwards in the shape of a V until it terminates in the 'affenspalte' which I have marked in brown in the following figure.

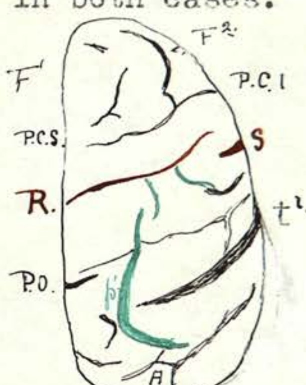


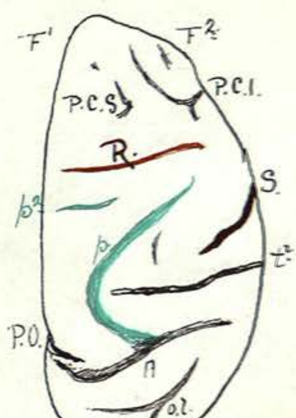
If this long fissure be opened up, it will be found that there are a number of deep gyri present. The first of these is situated at the point I have marked "A". This can scarcely be called a deep gyrus; it is rather a convolution over which a slight furrow passes connecting the anterior end of the intraparietal sulcus to the fissure of Rolando, but is quite distinct from both, being only a slight fissure about a quarter of the depth of the intraparietal sulcus. The second deep gyrus is situated at the point I have marked "B", i.e., at the junction of the intraparietal sulcus with the external parieto-occipital fissure. This gyrus is also traversed by a slight fissure which connects the two together, and also is quite separate from both. And lastly there is a third deep gyrus at the point I have marked "C", which thus limits the posterior end of the intraparietal sulcus. The intraparietal sulcus, therefore, is a more or less straight sulcus which becomes gradually deeper as we pass backwards where its depth is 16 mms. But, as I have already pointed out, there is a second fissure which passes backwards from the fissure of Rolando into the parietal region, and which I have marked "P.S." in the above figure. This fissure is in the form of a right angle, the two arms being of about equal length and measuring 25 mms. If this is opened up, it is seen to consist of three fissures, the most posterior of which, "R.S.", is the deepest. The middle, "Q.R.", is separated from the last by a deep gyrus and is only a shallow fissure, while the most anterior, "P.Q", is scarcely to be correctly called a fissure; it is just a slight indentation which connects the middle part of this fissure to the fissure of Rolando.



The condition on the right hemisphere is rather different, and the chief point which is at once brought to our notice is the position of the external parieto-occipital sulcus in relation to the intraparietal sulcus. In the left hemisphere the former was situated near the posterior end of the latter ; in the right hemisphere the external parieto-occipito sulcus lies close to the anterior extremity of the intraparietal sulcus, and this different position is due to a displacement of the whole intraparietal sulcus backwards, as is seen from the following figure, and in consequence of this the intraparietal sulcus has become so closely connected with the occipital region that I cannot discuss it fully until I have described also this latter region. The intraparietal sulcus consists of a large, well-marked, deep semilunar fissure, which is arranged round the end of the temporal fissure. Posteriorly it is connected with the Affenspalte (see Fig. in brown) by a slight feebly-marked fissure, and anteriorly a quite unusual condition is present, namely four fissures appear to meet at this point, A (see Fig.) If this be opened up it will be found that the intraparietal sulcus is continued forwards into the most anterior of these fissures, while the two lateral ones are very much shallower and quite distinct from it. The condition of the intraparietal sulcus on this side is thus really the same as on the other, namely, it is a long, slightly curved and deep fissure, lying just posterior to the fissure of Rolando, and separated from the affenspalte behind by a deep gyrus. Anteriorly, I pointed out, that in the opposite hemisphere, there was a deep gyrus which prevented the union of this sulcus with the fissure of Rolando, and that the deep gyrus was traversed by a shallow sulcus. In this hemisphere this gyrus has risen to the surface and completely separates the intraparietal sulcus from the fissure of Rolando ; and also from a fissure which passes out backwards from the fissure of Rolando and corresponds to the slight fissure present on the opposite hemisphere. The fissure passing from the intraparietal sulcus to the external parieto-occipital sulcus (A.C.) corresponds to the similar sulcus present in the opposite hemisphere, only here it is longer and better developed ; while the remaining fissure (A.D.) is part of the temporal series of sulci, and which I shall discuss later. And lastly there still remains the lower of the two fissures which pass backwards from the fissure of Rolando, and which I have previously also referred to as the posterior arm of the terminal bifurcation of the fissure of Rolando. In this right hemisphere this arm is very well developed, cutting deeply into the substance of the hemisphere, and although it passes into the fissure of Rolando, it does not do so directly ; it is separated from it by a deep gyrus across which a shallow sulcus passes, uniting the two fissures together, but quite distinct from either.

When we come to consider the full signification of the changes here, just as in the frontal lobe, one is at once struck by its close resemblance to the condition found in the lower ape brain. This is well seen on comparing the following two figures, the one from the right hemisphere of Robert Lindsay, the other from the right hemisphere of a low ape (Semnopithecus). In both the intraparietal sulcus is in the form of an angular loop thrown round the upturned end of the temporal fissure, but there is this difference between the two brains that, while there are two fissures passing into the parietal region from the fissure of Rolando, there are none in the ape, thus showing that the resemblance is not absolutely the same in both cases.





Cunningham (p.320) discueses the intraparietal furrow as follows :-

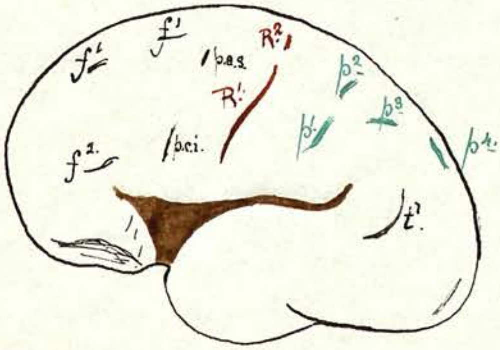
"In the normal human brain the intraparietal sulcus is built up of several pieces, which, as a rule, are developmentally distinct. In the ape the sulcus is much more simple, and in many cases appears in the form of a single fissure, which pursues an oblique course across the parietal lobe. This simple furrow in the process of evolution may be regarded as being the progenitor of the more complicated human sulcus, and by its disruption to give origin to three out of its four elements.

In many microcephalic brains we may remark a tendency to the simplification of the intraparietal sulcus, or, in other words, to a reversion to its original ape-like form. The two hemispheres of Fred afford an excellent example of this. The intraparietal sulcus is a single oblique furrow, which extends diagonally across the parietal lobe. Reaching the arcus parieto-occipitalis it sends a branch upward in front of this convolution and then bends downwards to join the "Affenspalte". Here there is almost an exact reproduction of what is seen in many of the lower apes. This single sulcus represents the sulcus post-centralis inferior, the ramus horizontalis, and the ramus occipitalis of the normal human brain. The sulcus postcentralis superior, which is to be regarded as a more or less independent element which has become linked on to the intraparietal furrow system in the human and higher ape brains, is entirely absent in both hemispheres of Fred".

This view is quite distinct. The intraparietal sulcus in man consists of three developmentally distinct fissures. In the ape there is only one, which represents these three together. In the microcephale there is only one, and as this one is similar to that in the ape, it represents these three also and thus may be looked on as a marked simian characteristic.

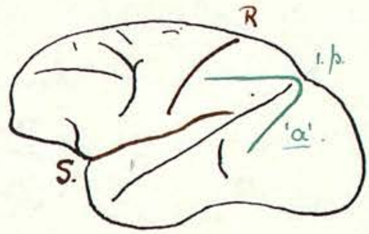
But this view is not quite correct, and also it affords no explanation of the two other fissures which pass backwards from the fissure of Rolando into the parietal region and which are not found in the ape brain, either low or high. And just as I showed in the frontal lobe, so also here the superposition of an ape-like type of brain upon a partially developed normal foetal brain affords an explanation which is so complete that it is difficult to come to any other conclusion but that it at least approaches closely to the truth. It is not possible for me to demonstrate the corectness of this view, and the rather important conclusions deduced from it, at this stage. The proof will be found later. I only wish to point out that the condition found in the brain of Robert Lindsay is consistent with this view.

I shall first point out the condition found in the foetal brain and then in the ape brain. A very typical picture of the development of the intraparietal sulcus is found in the following figure which I reproduce from Professor Cunningham's Memoir, Plate ii, Fig. 18.



Here it will be seen that the parietal region exhibits four separate sulci, and of these p^1, p^3 and p^4 correspond to the single intraparietal sulcus of the ape.

Now let us examine the following reproduction of the brain of a Macacus sinicus, No.594, Catalogue of the Museum of the Roy. Coll. of Surg. Eng., 1902, p. 410.

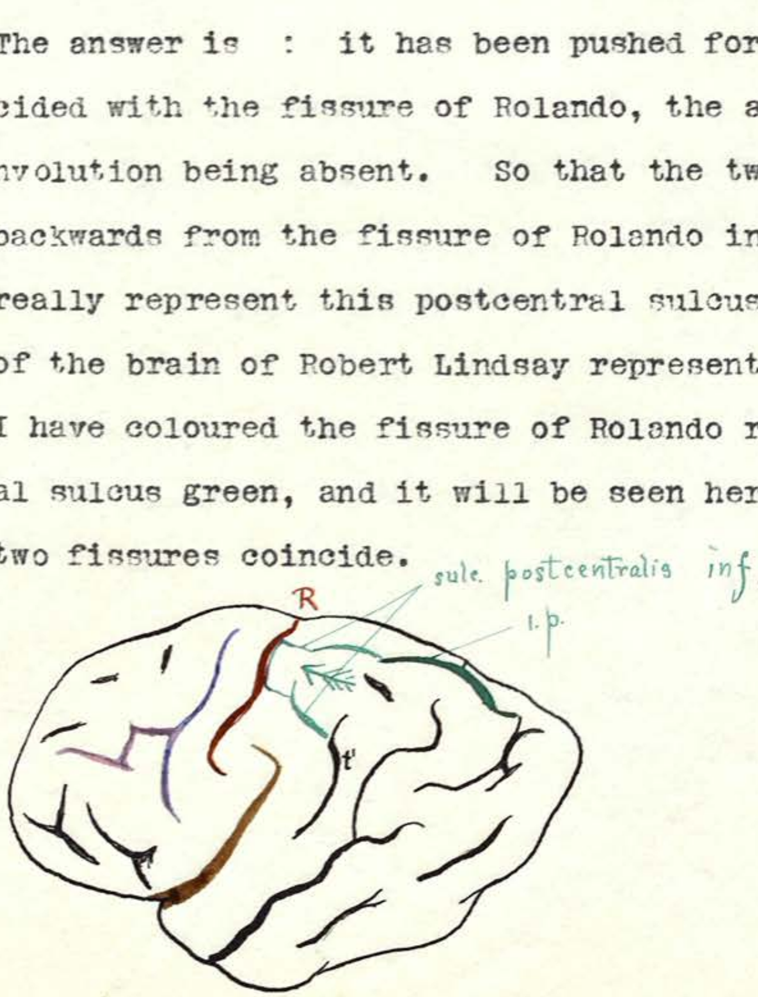


Here the single intraparietal sulcus is well marked and strongly developed, and exhibits its typical arched form, with the first temporal sulcus passing upwards towards the centre of the arch.

Let us now superpose this latter condition upon the former and learn what condition will result. In the ape the intraparietal sulcus is deep and prominent, and arranged round the first temporal fissure. So in the microcephalic brain this condition will be simulated, but as the brain has already developed normally for a certain length, this deep sulcus will be superposed upon the sulci already present or in process of development, and thus the resulting appearance cannot resemble the ape to any very exact degree. The important point, however, is this :- if this ape-like intraparietal sulcus be superposed on the embryonic brain, it will be upon the sulci which occupy the corresponding position, i.e., the ramus horizontalis and the ramus occipitalis. The sulcus postcentralis inferior will not take any part in this new intraparietal sulcus, as it is situated too far away. The condition, therefore, may be summarised as follows :-

1. The intraparietal sulcus in the apes is a single deep fissure ;
2. In man it is broken up into three elements which arise separately ;
3. In the microcephale, where the ape condition is superposed on the foetal, the ape intraparietal sulcus is not superposed upon all three elements, but on only two.

Having determined this point, we next have to consider what has become of this third element, the sulcus postcentralis inferior ? The answer is : it has been pushed forwards until it has coincided with the fissure of Rolando, the ascending parietal convolution being absent. So that the two fissures which pass backwards from the fissure of Rolando into the parietal region really represent this postcentral sulcus. The following figure of the brain of Robert Lindsay represents this view clearly. I have coloured the fissure of Rolando red, and the intraparietal sulcus green, and it will be seen here in what manner the two fissures coincide.



A view of such far-reaching importance as that above described, including the absence of the ascending parietal convolution can, however, scarcely be considered to be adequately supported by the examination of one single brain, and therefore I must ask for criticism to be withheld until a little further forward in this paper, when I shall discuss the variation found in other microcephalic hemispheres and show that it is possible to trace a complete series containing all the intermediate steps between the condition found in Robert Lindsay on the one hand, and a condition resembling the human brain so far that it is not possible to mistake the true nature of the fissures.

I shall just conclude the description of the parietal region at present by stating again that it presents a condition which is not exactly comparable to either the ape or foetal brain, and can be explained fully by the superposition of an ape-like type of brain upon a foetal brain and therefore presents features which are characteristic of the microcephalic brain alone.

The Occipital Region :

Special interest is attached to this region in the microcephalic brain because of the very complete knowledge which we possess of the morphology of this part of the brain, both in man and the apes, from the work of Elliot Smith.

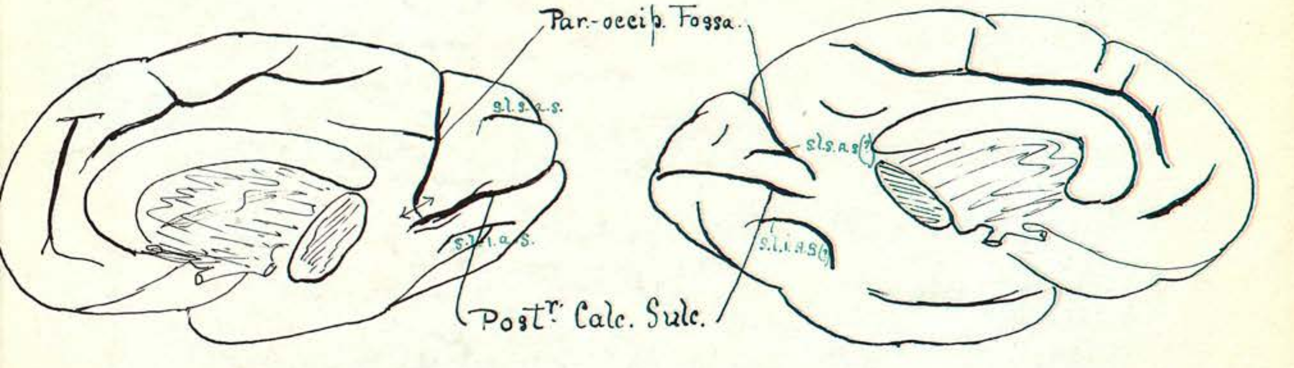
Elliot Smith (Studies in the Morphology of the Human Brain, No.1 : The Occipital Region, 1904; Vol.ii, Records of Egypt. Gov. School of Med.) in a very exhaustive paper has pointed out that the cortex of the occipital region contains a stripe or streak known as the "stria Gennari," which "is of the utmost value in identifying homologous sulci in different brains". He has pointed out that this streak of Gennari is well-marked and ends very abruptly and possesses definite relations to certain furrows, and also that the distribution of this streak is different in the apes and in man, and affords us a very satisfactory method for determining and comparing the condition found in the ape with that in man. But before discussing the views of Elliot Smith on this subject, I shall describe the appearance of the occipital region in the brain of Robert Lindsay, and it is convenient to do so under three headings :-

1. Calcarine Region ;
2. Parieto-occipital Region ;
3. Lateral Occipital Region.

I shall adopt mostly the most recent nomenclature of Elliot Smith.

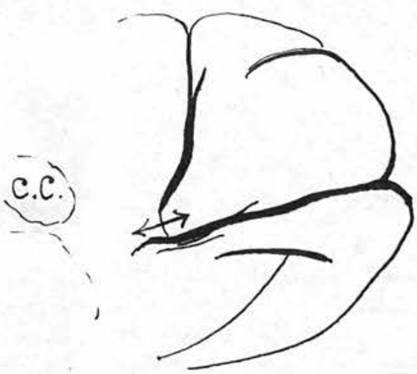
1. The Calcarine Region :

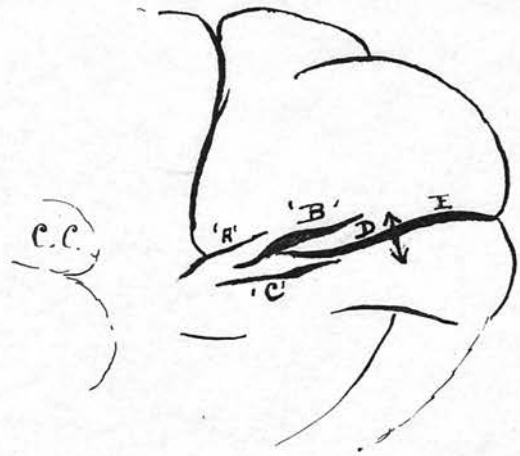
The calcarine fissure is extremely well marked in both hemispheres, but differs slightly on the two sides. On the left hemisphere the calcarine fissure consists of a single, long, deep, well-marked sulcus, which commences at 20 mm. behind the posterior end of the corpus callosum and runs straight outwards towards the occipital pole. It is not, however, continued round the margin of the hemisphere in to the lateral occipital region. This fissure is the posterior calcarine fissure of Cunningham (Retrocalcarine of Elliot Smith), and there is no trace whatever of an anterior calcarine fissure. If this posterior calcarine fissure be opened up, it will be found to be very deep, measuring 13 mm., and to show no signs of any deep gyri ; it is a single, deep fissure running straight backwards and limited to the mesial wall. It is bounded above and below by two very well-marked sulci, the sulcus limitans superior area striata, and the sulcus limitans inferior area striata (Elliot Smith). These two sulci mark the limits of the striate area. The superior sulcus passes directly into the



parieto-occipital fissure, which, therefore, forms the boundary superiorly of the posterior end of this area striata. (See later) The inferior sulcus curves forwards and outwards and comes to assume the form of a quadrant of a circle, (see Fig.).

On the right hemisphere the condition is still more interesting. Superficially the calcarine sulcus appears to consist of a single sulcus which passes more or less directly backwards across the mesial wall of the occipital region. It commences as a small shallow sulcus, mms. behind the posterior end of the corpus callosum and passes backwards, suddenly gets deeper, and after a slighter upward curve ends just at the occipital pole. If this fissure be opened up, the condition will be found to be quite different. It does not consist of a single deep fissure as in the opposite hemisphere; instead it is here broken up into five separate sulci (see Fig.).





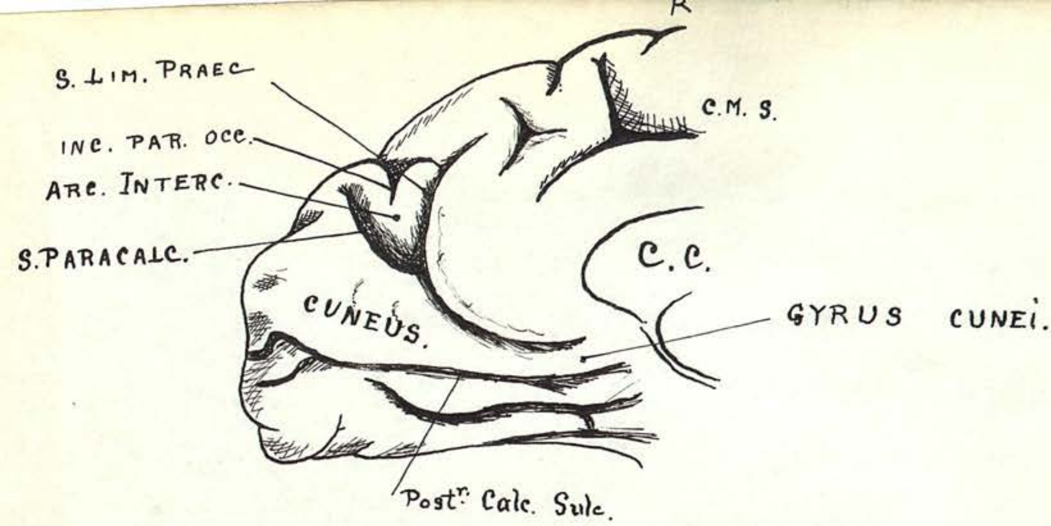
Of these the first is the shallowest. I have marked it "A" in the above diagram. It commences below the parieto-occipital fissure and passes upwards and backwards and ends close to, but does not actually unite with the second fissure, which is much deeper, and which I have marked "B". At the end of its anterior third it unites with the lower end of the parieto-occipital fissure, so that in this hemisphere the gyrus cunei is not on the surface as is the condition in the opposite side. The second fissure is much deeper and measures 16 mm. in length. If the fissure is closed, it will be found that the superior margin completely overlaps the inferior, so that it is scarcely possible to see into this fissure clearly. It is chiefly to be noted on account of its great depth. The third fissure, "C", is sisuated below the last two; it measures 9 mm long, and is almost the same depth as the first fissure "A". The next fissures I have marked "D" and "E". They may almost be considered as one fissure, the reason that I have divided it into two being the presence of a deep gyrus or rather buttress, projecting upwards from below just at the spot I have placed the arrow. This fissure is the longest of all ; it measures 33 mm ~~by~~ ~~mm~~, and is deepest at the middle (14 mm).

The calcarine sulcus on this hemisphere, therefore, consists superficially of a long single fissure, which on being opened up is found to consist of four separate and distinct fissures all running more or less parallel to each other and cutting deeply into the substance of the brain. Of these fissures, there is no doubt that the last three represent the posterior calcarine sulcus of Cunningham; the first from its relation to the lower end of the parieto-occipital fissure probably represents a small anterior calcarine sulcus (which is absent in the opposite hemisphere). And in this hemisphere also there are well marked, deep sulci above and below the calcarine fissure, corresponding to the sulcus limitans superior (and inferior) areae striatae.

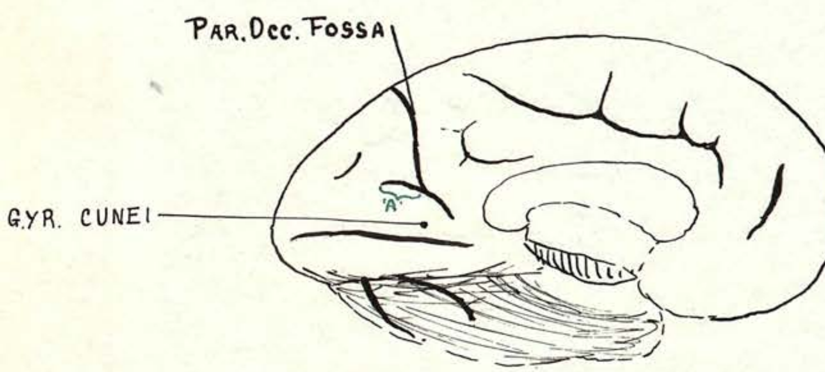
The Parieto-occipital Region :

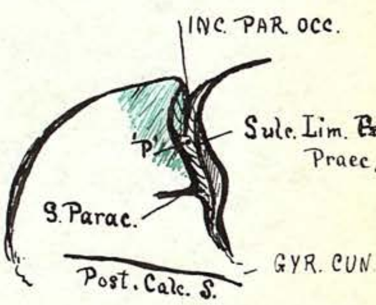
This region in both hemispheres is very simple. The parieto-occipital fissure is usually represented as a simple straight furrow on the mesial wall, the "internal parieto-occipital fissure", which cuts so deeply into the substance of the brain that it appears on the external surface where it is known as the "external parieto-occipital fissure".

Flashman (Reports from the Pathol. Lab. of the Lunacy Depart. N. S. W., Vol.i, 1908), and later Elliot Smith have shown that the parieto-occipital sulcus is really composed of three separate sulci, the two outer of which meet over the middle and form the deep cleft known as the internal parieto-occipital fissure. Of these three fissures, Elliot Smith has named the outer the "sulcus paracalcarinus", and the inner "the sulcus limitans praecunei", while the middle sulcus consists of a deep notch in the dorso-mesial edge of the hemisphere and is surrounded by two U-shaped limbs, bent at right angles to each other - the vertical arcus intercuneatus on the mesial surface, and the horizontal arcus parieto-occipitalis on the dorsal surface. In the European brain these two outer sulci usually meet and close in the arcus intercuneatus, but in low types of human brains and also in various ape brains this arcus comes to the surface owing to the failure of the two lateral sulci to meet and cover it, as is seen in the following figure from the brain of a chimpanzee.



Having now understood the arrangement of the sulci in the parieto-occipital region, we are in a position to consider the condition found in the brain of Robert Lindsay. In both hemispheres the arrangement is remarkably simple. On the left hemisphere superficially, the parieto-occipital fissure extends across the cuneus in the manner shown in the following figure. Inferiorly it is separated from the calcarine fissure by a prominent gyrus cunei. It passes upwards and outwards and cuts deeply into the dorsal wall of the hemisphere. From its middle point a small fissure passes backwards for a distance of 5 mm. If we now open up the internal parieto-occipital fissure, it will be seen that the condition is peculiar. At the point marked P.,





there is a gyrus which marks the foot of the arcus intercuneatus, of which the shaded part alone appears to form the posterior arm.

The arcus intercuneatus in this hemisphere is represented by a very large and prominent posterior arm and a very small and insignificant anterior arm. The fissure which is seen on looking at the mesial wall of the hemisphere represents the "internal parieto-occipital" and is the "sulcus limitans praecunei" of Elliot Smith. Its course is best seen from an examination of the above diagram. It is 20 mm long and 7 mm deep. It is not quite a perpendicular furrow; it slopes slightly forwards from within outwards, but to such a slight extent that I cannot say that there is a definite operculum (i.e. "anterior opercular lip of the internal parieto-occipital fossa"). I have already pointed out that there is a small fissure passing backwards from the middle of the internal parieto-occipital fossa. This small fissure is marked 'A' in the above figure. I have apready stated that it may represent the sulcus limitans superior areae striatae. But it is still more probable that it really represents the "sulcus paracalcarinus" of Elliot Smith. As I have not cut into the brain I cannot prove this point precisely by determining where the streak of Gennari ends. It is a straight fissure 5 mm long and 2 mm deep, and passes into the parieto-occipital fossa to unite with the sulcus limitans praecunei at right angles. It shows absolutely no trace whatever of a posterior operculum, (i.e. posterior opercular lip to the parieto-occipital fossa). I may, therefore, summarise the condition of the parieto-occipital region as follows :-

The parieto-occipital fossa consists of three furrows which are separated from one another ;

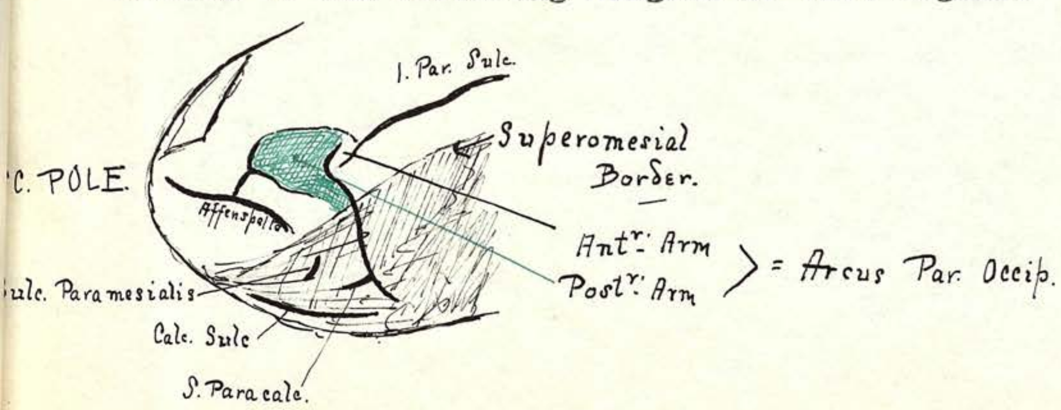
The anterior (sulcus limitans praecunei), is a straight furrow rather deeply cut and occupies the greater part of the fossa.

The posterior (sulcus paracalcarinus) is a short furrow situated at a right angle to the other, and meeting it at about its mid point.

The middle (incisura parieto-occipitalis) is a short furrow, which cuts deeply into the substance of the brain and lies very much in the same straight line as the sulcus limitans praecunei.

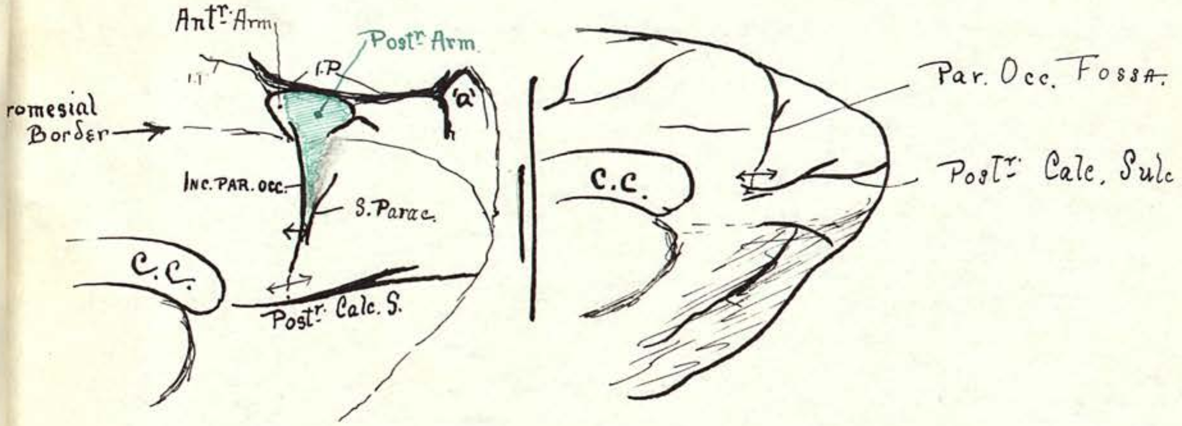
The anterior and posterior opercular lips have not developed and thus the sulcus paracalcarinus and the sulcus limitans praecunei, although they close in the lower part of the fossa, do not meet in the upper, and thus the arcus intercuneatus rises to the surface. This arcus is characterised by the great development of its posterior arm, which alone is seen on the mesial surface and which, being associated with an extremely poorly developed anterior arm, has pushed the incisura parieto-occipitalis so far forwards that it lies in the same line as the sulcus limitans praecunei.

The above description will perhaps be understood by referring to the following diagram of this region.



It will also be noted that there is a small fissure present which I have marked P.M. This probably represents the sulcus paramesialis of Elliot Smith.

The right hemisphere of Robert Lindsay exhibits a slightly different arrangement, which is simpler than that of the opposite side and is easily understood. The appearance of the parieto-occipital fossa is seen in the following figure. It consists of a deep fissure, passing upwards and slightly backwards. At its origin it is united to the calcarine fissure and thus the gyrus cunei does not rise to the surface as in the opposite hemisphere. If this fissure be opened up, the condition is at once



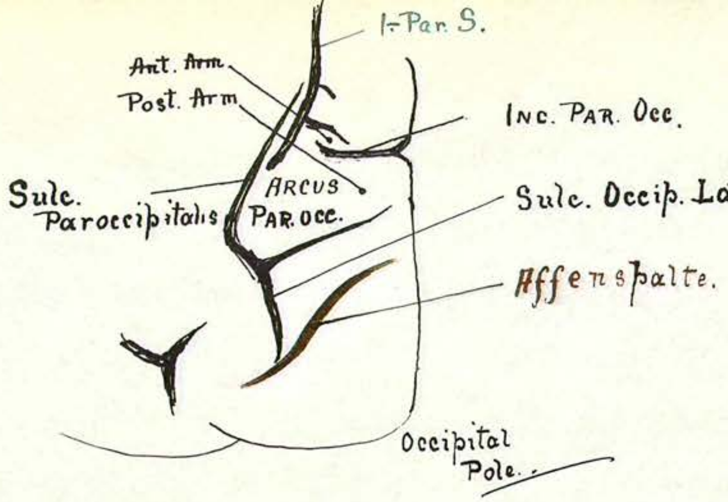
apparent. The sulcus limitans praecunei is absent; the sulcus paracalcarinus is present, and the incisura parieto-occipitalis passes directly downwards to the foot of the fossa, and it is into this fissure that the sulcus paracalcarinus passes at right angles. There is thus no arcus intercuneatus, but that part of this vertical fissure which is situated below the point where the sulcus paracalcarinus joins it, is deeper than the upper part. It is interesting to note that though the arcus intercuneatus is absent, the posterior arm of the arcus parieto-occipitalis is very strongly developed, and it is its prolongation downwards on to the mesial surface which lies between the incisura parieto-occipitalis and the sulcus paracalcarinus, and the absence of the arcus intercuneatus is mostly due to the failure in the development of this anterior arm. The resemblance to the opposite hemisphere is therefore very close. In the one case the anterior arm is not developed, and the arcus intercuneatus is absent; in the other case it is just sufficiently developed to separate the incisura from the fissure below and thus form an arcus intercuneatus; and in both hemispheres it is the posterior arm only which is seen on the mesial surface.

The Lateral Occipital Region :-

This region is specially interesting owing to its relation to the sulcus known as the Affenspalte. This sulcus is a very prominent feature in the ape-brain. Its identification in the human adult brain has been disputed, but it has been shown by Elliot Smith that a curved sulcus usually present on the lateral occipital region is the homologous sulcus. This sulcus he has named the "sulcus lunatus", and he founds his argument upon the fact that the stria of Gennari stops at the anterior border of the Affenspalte in the ape, and at the anterior border of this sulcus lunatus in man. He has shown that this sulcus lunatus is present in Egyptian (70 %, p.149), Soudanese and Balkan brains. It is found in the Australian aboriginal brain (Ducknoth). It is depicted in the Swedish brain by Retzius. I have myself found it in the Indian brain. It is thus an extremely constant sulcus, but if the European brain be examined, especially those of this city, it will be at once noticed that this sulcus is not present to the same extent as in thise abovementioned brains. In many of them I have been quite unable to convince myself of its presence. Cunningham (p.323) has pointed out that "a retention of the Affenspalte is a very common feature in the microcephalic brain, and in not a few cases it is accompanied by a true occipital operculum as in the ape".

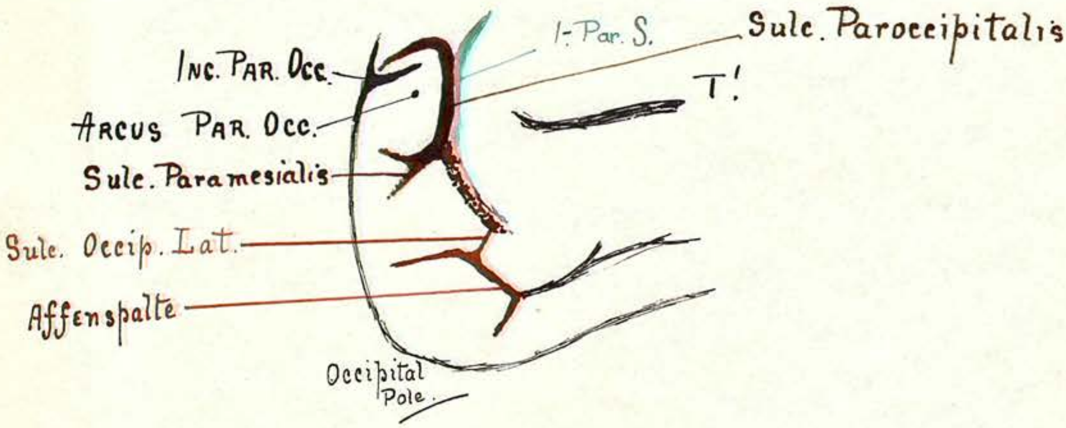
In both hemispheres of Robert Lindsay there is a well marked but not very extensive Affenspalte, or sulcus lunatus.

In the left hemisphere the sulcus lunatus is easily recognisable. It is that sulcus which I have marked in red and takes the form of a small, slightly curved fissure, situated close to the occipital pole. It is of no great depth and can scarcely be said to be opercular. The calcarine fissure, if continued round the occipital pole, would bisect the sulcus lunatus. Extending forwards from the sulcus lunatus is a short sulcus 5 mm long, which passes directly into the ramus occipitalis of the intraparietal sulcus (i.e. the sulcus paroccipitalis of Elliot Smith). This sulcus is the sulcus occipitalis lateralis

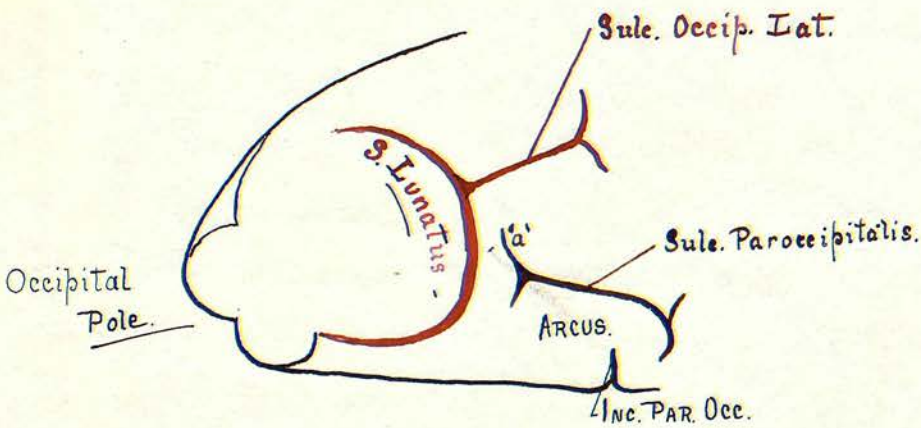


(sulcus praelunatus of Elliot Smith - see Journ. Anat. and Physiol., 1907). There is no trace of any external calcarine sulcus.

On the right hemisphere the arrangement is somewhat different and not at first sight easy to understand. If the following diagram be carefully examined, it will be seen that the short



curved sulcus I have marked in red obviously corresponds to the sulcus which in the opposite hemisphere I have called the sulcus lunatus, and with this view I agree. It is of a similar form and is in the same position, situated round the end of the calcarine fissure, and moreover there is a small fissure passing forwards from it (also marked in red) to meet the intraparietal sulcus, which is clearly the sulcus occipitalis lateralis, (or sulcus praelunatus). And there is no doubt that the other fissure which I have marked in brown represents the sulcus paroccipitalis of Elliot Smith (ramus occipitalis of intraparietal sulcus). It clearly limits the arcus parieto-occipitalis. But it is a question of far greater difficulty to determine the nature of the sulcus which I have marked with an interrupted red line ; it connects the sulcus lunatus with the paroccipital fissure and has no hoomlogue in the opposite hemisphere. And there is also another small V-shaped fissure, which I have marked with an interrupted brown line. This latter fissure, I think, is the sulcus paramesialis of Elliot Smith, which has been displaced outwards, whilt the former probably is an unusually long branch of the sulcus paroccipitalis. This will perhaps be best understood by examining the following figure from Elliot Smith's paper in the Journ. of Anat. and Physiol., 1907, "On the Folding of the Visual Cortex and the Significance of the Occipital Sulci in the Human Brain".

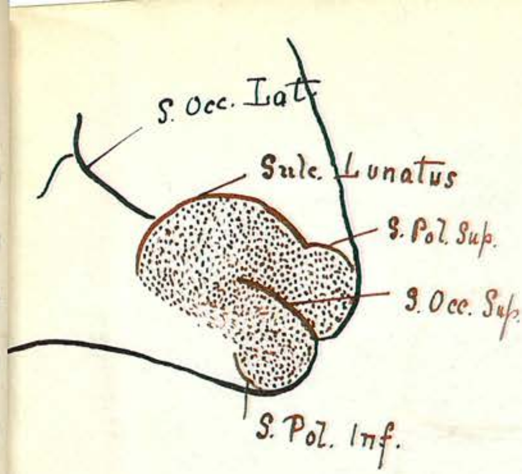


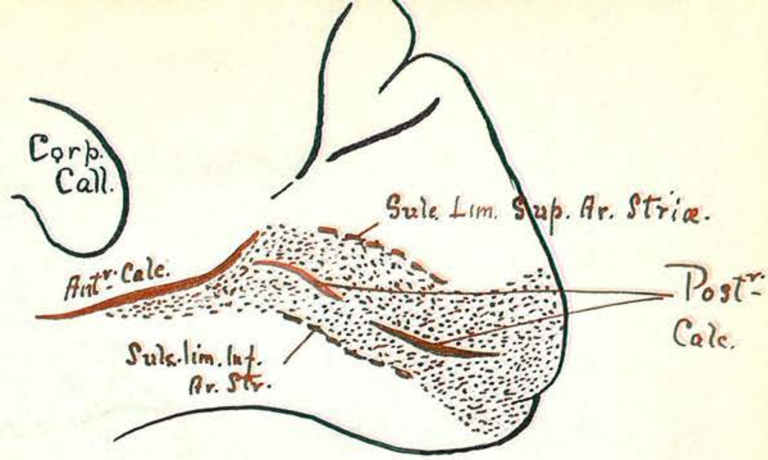
In this figure the paroccipital sulcus is shown as a curved sulcus surrounding the arcus parieto-occipitalis, and two branches pass away from it at either end. These branches are of quite different lengths in different brains, and it would appear that in the microcephalic brain we have a shortening of the occipital visual cortex and an extension backwards of the branch (which I have marked "a" in the above figure), until it reaches the sulcus occipitalis lateralis. I cannot, however, prove this point, as I have not cut up the brain to determine the streak of Gennari.

Having described the condition and relation of the fissures in the two hemispheres, I now propose to discuss their significance.

The streak of Gennari is found over an area to which Elliot Smith has applied the term the "area striata", and this area "may be mapped out with the utmost ease and accuracy". Its great importance from the point of view of the microcephalic brain lies in the fact that it is differently arranged in man and in the apes. In man the arrangement is as follows :-

It commences anteriorly on the mesial wall of the hemisphere at a well-marked fissure, the Anterior Calcarine Sulcus (which is its anterior boundary). It then passes backwards to the occipital pole. During this part of its course there are found in it two or more fissures, the posterior calcarine sulcus of Cunningham (retrocalcarine sulcus of Elliot Smith). It is usually bounded above and below at this stage by two fissures, the sulcus limitans superior (and inferior) areae striatae. It then turns round the occipital pole of the hemisphere and appears

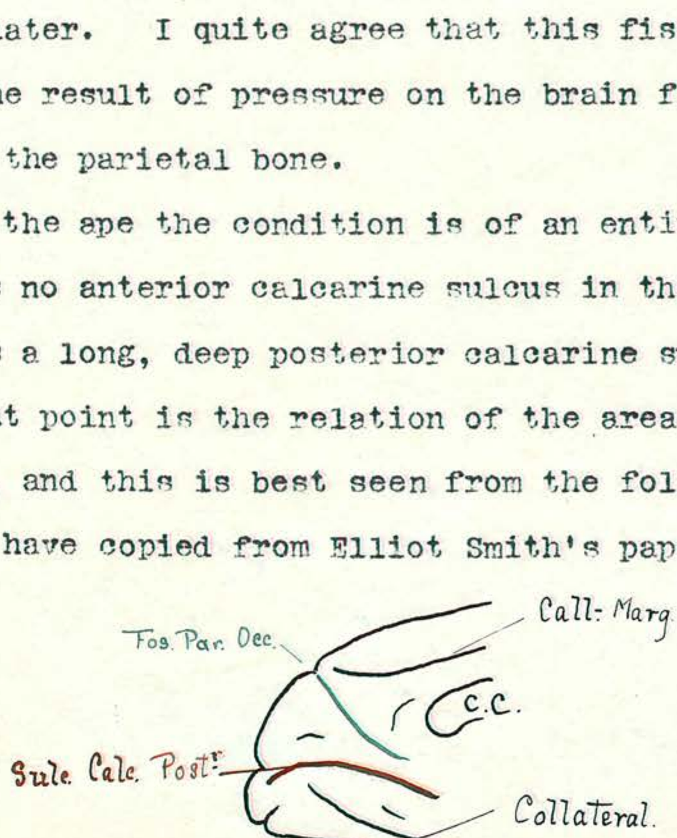




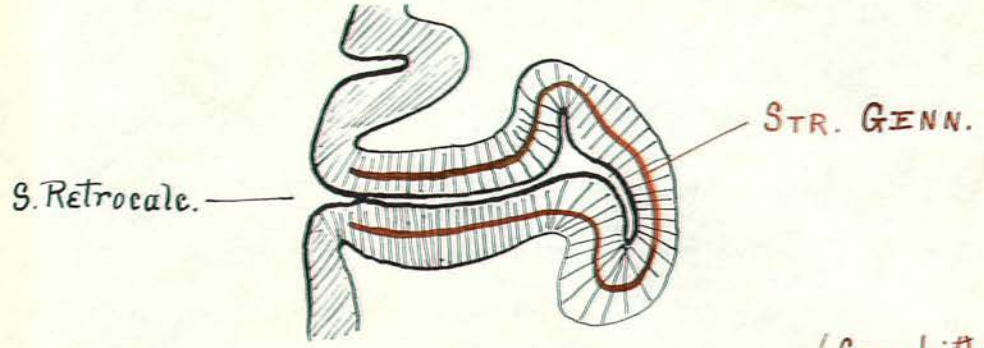
on the lateral wall. As it turns round it is usually limited above and below by two shallow sulci, the sulcus polaris superior and inferior. On the lateral wall it spreads out into a wide area, which extends as far as the sulcus lunatus in front, and the sulcus occipitalis inferior below. Within this area there is a well-marked fissure, the sulcus occipitalis superior.

In the human foetus there is a fissure found at the fourth and fifth months in the position which the sulcus lunatus occupies later. I quite agree that this fissure is post-mortem, being the result of pressure on the brain from the posterior wall of the parietal bone.

In the ape the condition is of an entirely different nature. There is no anterior calcarine sulcus in the ape. Instead there is a long, deep posterior calcarine sulcus. But the important point is the relation of the area striata to these furrows, and this is best seen from the following two figures which I have copied from Elliot Smith's paper.

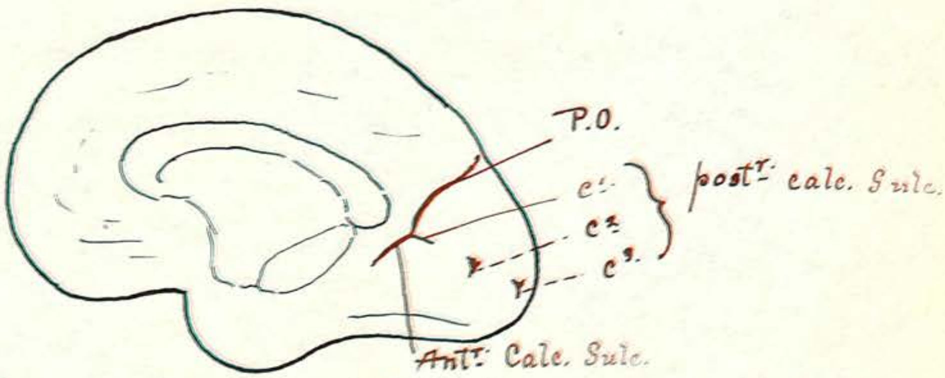


Semnopithecus. p142. E. Smith



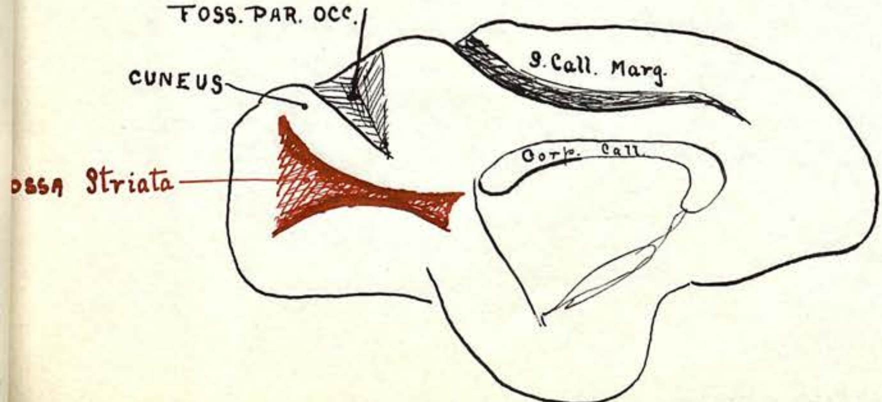
(Cercopithecus)
p. 141).

In man the area striata lines both the interior of the fissure and extends along the surface of the brain to the superior and inferior limiting sulci as well as forwards to the edge of the anterior calcarine sulcus. But in the ape, the area striata is limited solely to the interior of the posterior calcarine sulcus (see Fig.). And the development of this area is different in man from that in the ape. In man the anterior calcarine sulcus is first formed, and then as the area striata develops it shows two (or three) small indentations on its surface. These ultimately run together to form the posterior calcarine sulcus.



But in the apes the area striata is very large indeed. "A small Cercopithecus with a brain less than one-twentieth the size of an average human brain may have an area striata as big as that of the human brain. In all apes the cortical area containing the stripe of Gennari is relatively much larger, and in many actually bigger than it is in the human brain. This implies that in the developmental history of the Simian brain the disproportion between the rates of growth of the area striata and the rest of the cortex is vastly different from that of the human brain. More than that, the growth of the area striata must be, and as a matter of observation is, precocious in order to attain to the large absolute size which it reaches in the adult brain. This precocious development and rapid growth of the area striata produces an involution of the whole region and thus calls the sulcus retrocalcarinus (i.e. posterior calcarine) into being at such an exceptionally early period that its mechanical prolongation into what we may call the "calcarine territory" relieves the tension of the growing cortex, so that there is no call for a real calcarine sulcus (i.e., anterior calcarine). Another result is that the whole of the mesial part of the area striata becomes involuted to form the retro-calcarine sulcus in the apes, probably because it grows so rapidly".

This is very well demonstrated by Elliot Smith in a foetal Hylobates brain which I have here reproduced.



no trace of an anterior calcarine sulcus, and the gyrus cunei comes prominently to the surface. The resemblance is, in fact, most striking.

In the right hemisphere, the condition is rather different. Here we have four separate and deep sulci, and the condition is not exactly directly comparable to the ape. But again we get a complete explanation by the superposition of the ape type upon the foetal.

The brain has evidently developed here so far that the anterior calcarine sulcus has begun to form and the striate area has grown in the slow manner characteristic of the human brain. When this ape type was suddenly superposed, the striate area would especially undergo great changes and have to develop at a sudden rapid rate. As a consequence the puckering up will occur rapidly and in this case it has resulted in four different fissures all being formed parallel to one another, in order to find sufficient room for this sudden increase in the rate of growth of the area striata.

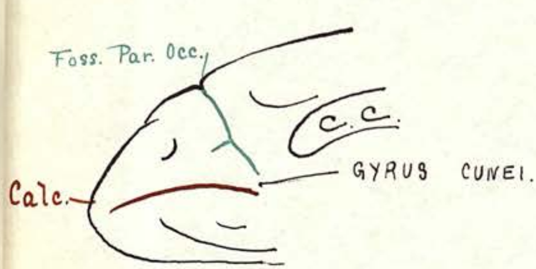
I am unable to make any statement in regard to the relation between the streak of Gennari and the posterior calcarine sulcus in this brain, as the brain has not been cut into.

The parieto-occipital region in the microcephalic brain also shows a great resemblance to the ape type. "In the brains of most genera of Apes, the arcus intercuneatus is exposed on the surface and the three furrows are widely separated

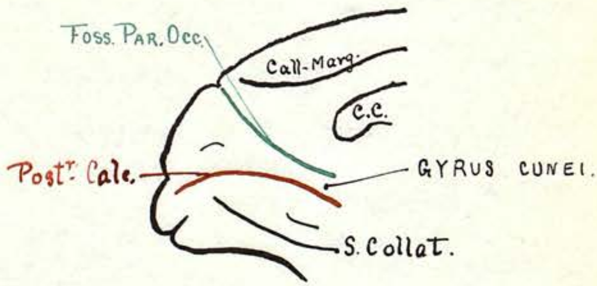
"Here the whole area has become depressed to form a large triangular fossa. This depression is partially overlapped above and below by two opercular folds. These folds gradually approach one another and when they meet the condition represented below results".

So in the ape (1) there is only present the posterior calcarine sulcus, and (2) the whole of the area striata is <u>within</u> this sulcus.

Having now understood the condition in man and in the ape, we are in a position to discuss what has occurred in the microcephalic brain. And the first fact to which I wish to draw attention is that in the left hemisphere the condition is almost directly the same as in the lower ape.

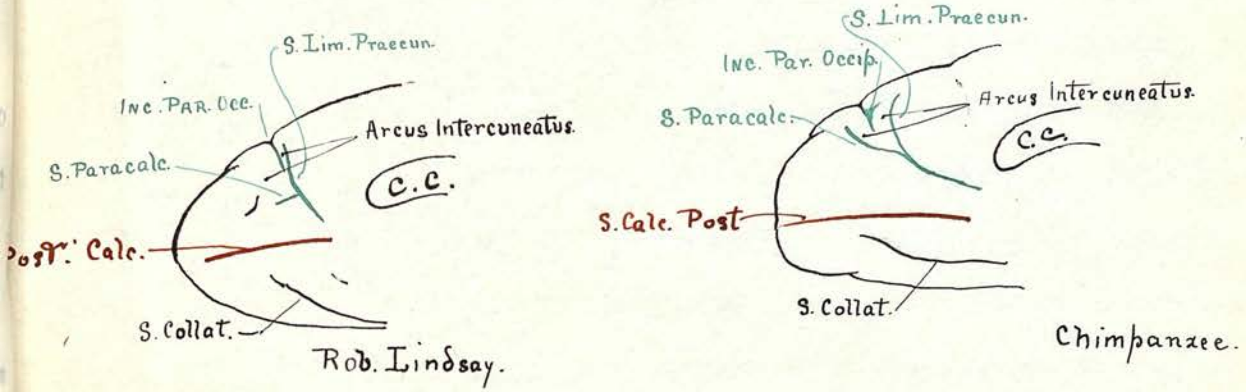


Robert Lindsay.



Semnopithecus.

I have attempted to show this from the above two diagrams, the right being from a Semnopithecus, and it will be seen that in both brains there is a sharply cut, very deep and unbroken fissure extending backwards towards the occipital pole. There is from each other. In such cases there is no "fissure" corresponding to that usually called "parieto-occipital", because none of the three independent furrows can be strictly so-called. The following figure of the brain of a chimpanzee exhibits the condition well. (See also brain of Gorilla, p. 146, Elliot



Smith;, Fig. 19; Quain's Anatomy, Fig. 289, p. 301, brain of Chimpanzee; and Fig. 291, p. 302, brain of Gorilla, Symington). Elliot Smith also states that "the above pattern occurs so often in the Gorilla, Chimpanzee and Cercopithecidae that it may be regarded as the normal condition for these genera". In the left hemisphere of Robert Lindsay I have already shown that this is the condition present, so that we have here a direct resemblance to the ape type. In the opposite hemisphere, I showed that there is no arcus intercuneatus and the incisura parieto-occipitalis is continued downwards into the sulcus limitans praecunei, a condition which is found in the lower ape brains.

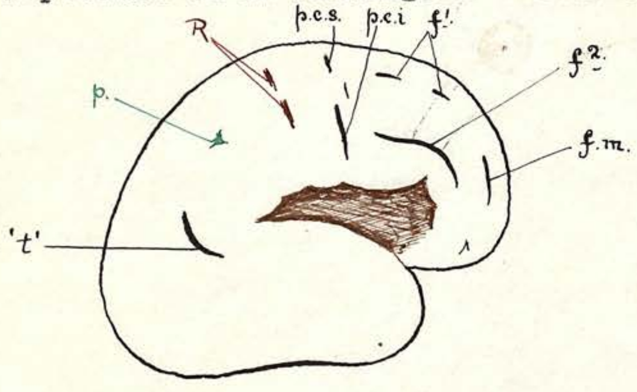
In the lateral occipital region, the presence of the Affenspalte is the most prominent feature. It does not bound a large operculum as in the lower apes. It rather resembles the condition described by Elliot Smith in the human brain. The explanation lies in the fact that the occipital visual fibres, i.e. the streak of Gennari, medullates early in the development of the brain. Flechzig (Gehirn und Seele) numbers this area of the cortex "4" in his diagrams. As this area is early medullated, when the development undergoes the remarkable alteration I have already described, this part will offer greater resistance to any superposed condition than will a part where the medullation occurs at a later period, and thus there is not the same sudden increase in the occipital operculum. The increase in growth of the visual cortex which is characteristic of the low ape type of brain has limited itself to the mesial surface, and has resulted in the development of a posterior calcarine sulcus of quite unusual depth (when compared with the human condition), and the obliteration of the anterior calcarine sulcus, and also in the formation of a small but definite Affenspalte, and therefore the close, but still incomplete resemblance of the occipital region of the microcephalic brain to the ape type meets with a full explanation in the superposition of a simple type of brain (resembling that found at present in the lower apes) upon a normal early foetal brain.

The Temporal Region :-

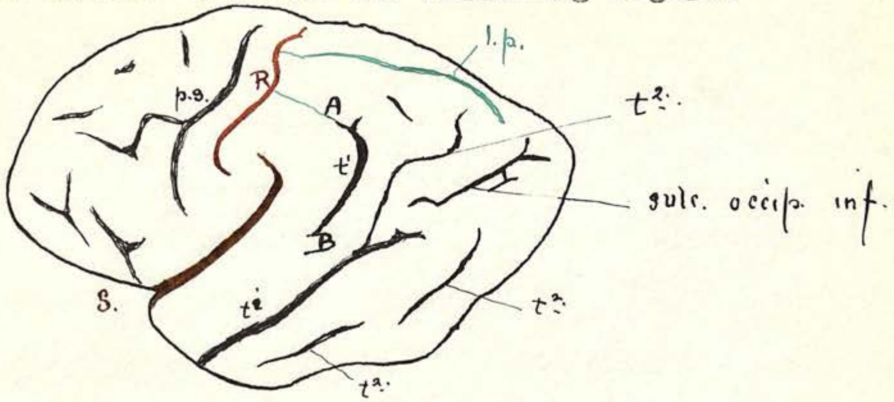
The temporal region in the microcephalic brain is a difficult region to understand fully. In considering the frontal and parietal regions, I have based my observation upon the work of Cunningham, and similarly in the occipital region, on the work of Elliot Smith. But the temporal region has not yet been systematically worked out in the same careful manner.

In the microcephalic brain, the forward rotation of the fissure of Rolando has resulted in a great increase in the size of the temporal lobe, which has also been affected by the changes which I have already shown have occurred in the parietal and occipital areas. (I shall discuss the relation of these areas to one another later).

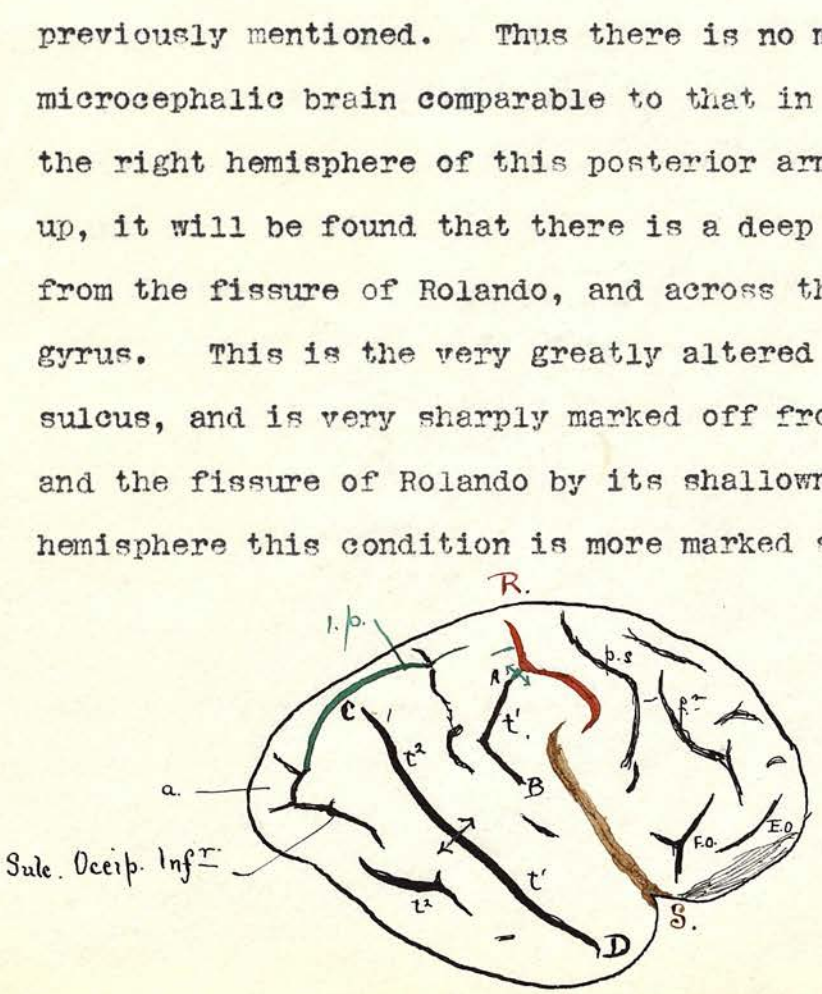
There is one furrow which is present in the temporal region at an early stage, and is the first sulcus to be differentiated, and that is the one which is marked "t" in the following figure which I reproduce from Cunningham's Memoir, Plate i, Fig. 24.



It will be seen that this fissure curves round the posterior end of the fissure of Sylvius. When the fissure of Sylvius rotates forward in the microcephalic brain, it will carry this fissure with it. And in the brain of Robert Lindsay it is at once possible to identify this fissure. It is the fissure which I have marked "A B" in the following figure.

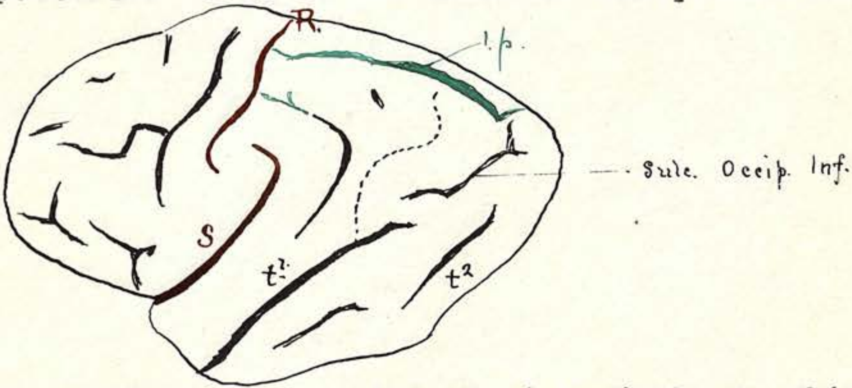


On the right hemisphere, however, the condition is one to which I wish to draw special attention. This furrow has been displaced forwards with the fissure of Rolando and has united with the lower end of the fissure of Rolando, and it is this furrow, the sulcus angularis, which forms the posterior arm of the terminal bifurcation of the fissure of Rolando which I have previously mentioned. Thus there is no marginal gyrus in the microcephalic brain comparable to that in the human brain. If the right hemisphere of this posterior arm be carefully opened up, it will be found that there is a deep gyrus separating it from the fissure of Rolando, and across this there runs a shallow gyrus. This is the very greatly altered inferior postcentral sulcus, and is very sharply marked off from the sulcus angularis and the fissure of Rolando by its shallowness. In the left hemisphere this condition is more marked still. The sulcus



angularis is situated far from the fissure of Rolando (see Figs.)

There is also another fissure which is easily recognisable, the one I have marked "C D". It is a long, deep, sharply marked fissure beginning at the temporal pole and passing upwards and backwards to end near the centre of the intraparietal sulcus. When opened up, it is seen to be traversed by a deep gyrus at its mid-point, (where I have placed the arrow). It is deeper below this than above. It is bounded by more or less perpendicular walls, except in the upper half of the lower part. Here it is markedly opercular, the fissure suddenly dipping underneath the anterior wall. The upper half of this fissure represents the anterior occipital sulcus, i.e. the upper part of the inferior temporal sulcus, the lower, the superior temporal sulcus. In the opposite hemisphere these two fissures are separated from each other by a more marked deep gyrus. Posterior to this furrow lies the inferior temporal sulcus in the left hemisphere in two parts, in the right in only one ; and lying posterior to it is the inferior occipital fissure.

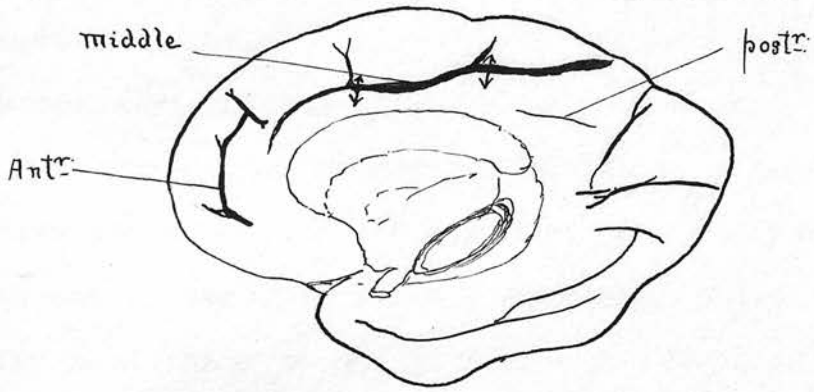


There is one other fissure on the right hemisphere, which is very difficult to understand. I have marked it with a dotted line in the above figure. I think it represents the upper part of the ~~inf~~ superior temporal sulcus. It is interesting to note this displacement backwards, seen in the right hemisphere, of the lower part of the superior temporal sulcus, until it comes to lie in the same straight line with the upper part of the inferior temporal ~~operculum~~ sulcus. After I had decided that this was the interpretation of the condition here, I found that Cunningham had come to exactly the same conclusion from examining the brain of Fred.

In the left hemisphere, a condition is present which almost seems to prove that this view is correct. Extending outwards and forwards from the Affenspalte is a furrow which represents the sulcus occipitalis inferior. This fissure lies between the upper part of the inferior temporal sulcus and the superior temporal sulcus, and thus prevents the possibility of these two fissures being found in the same straight line. On the right hemisphere this sulcus occipitalis inferior lies posterior to the upper part of the inferior temporal sulcus, and thus has ~~prevented~~ allowed its apparent union with the superior temporal to ~~join~~ form the long, large deep furrow found stretching across the hemisphere so prominently.

The Calloso-marginal Sulcus :

The calloso-marginal sulcus is well marked on both hemispheres of Robert Lindsay, and exhibits some very interesting conditions. In both hemispheres it consists of three separate



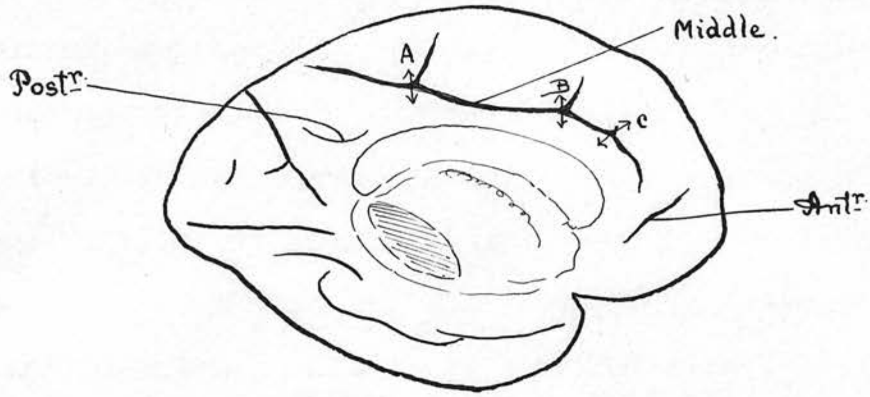
elements, a small posterior, a long deep middle, and a short anterior sulcus.

In the right hemisphere, these are well seen in the above diagram. The most posterior sulcus arises close to the parieto-occipital fossa and passes horizontally forwards for a distance of 12 mm. The middle sulcus is the most prominent. It arises immediately above and in front of the corpus callosum and passes backwards in a manner best shown by the above figure. It first runs parallel to the corpus callosum, for a distance of 18 mm. It then approaches the upper border, passing backwards and upwards for a distance of 15 mm. in a gentle curve, and finally, after another gentle curve, it terminates close to the supero-mesial border of the hemisphere, 8 mm. in front of the incisura parieto-occipitalis. I may therefore divide this sulcus into three parts, and at each junction there is a shallow sulcus passing outwards towards the supero-mesial border. Both of those are very shallow sulci, the more anterior being merely a depression in the surface. The sulcus itself, however, is not of an equal depth throughout its extent. The anterior third is relatively shallow, while the posterior two-thirds are deep, sharply-cut and sloping downwards and outwards, so that the callosal gyrus overlaps the marginal gyrus to a slight extent. There are two deep buttresses passing upwards from the callosal convolution at the anterior and posterior thirds respectively.

The most anterior sulcus is 25 mm. long, and terminates at both ends in a T-shaped manner. It is deep at its anterior end and gradually becomes shallower as it is traced backwards, finally coming to the surface just before it reaches the posterior T-shaped ending, so that it is more correct to speak of it as a short sulcus situated at right angles to the above and separated from it by a small superficial gyrus.

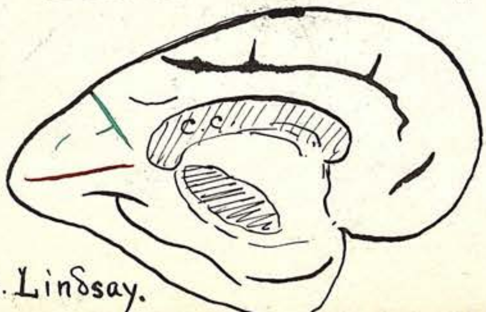
In the left hemisphere the condition is somewhat similar. The posterior sulcus is short and shallow. It commences about 5 mm. in front of the parieto-occipital fossa and passes horizontally forwards with a slight curve for a distance of 15 mm. The middle sulcus is again the longest, and may also be divided into three (or rather four) parts. It commences 5 mm. anterior to the corpus callosum and extends upwards and backwards to end on the supero-mesial border of the hemisphere, 5 mm. in front of the external parieto-occipital fissure. It varies very considerably in depth and presents several annectant buttresses.

These annectant buttresses are three in number, and are situated

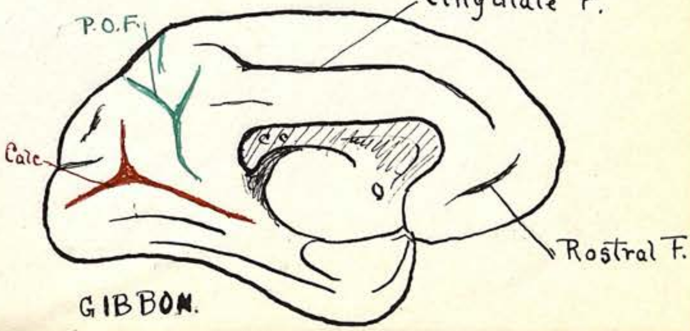


at the points marked "A" "B" and "C" in the above diagram. They all project upwards from the callosal gyrus. The anterior third consists of two parts which are evidently developmentally separate. The middle third is bordered by more or less parallel walls, but the posterior third is most markedly opercular, the lower lip overlapping the upper.

The complete development of the calloso-marginal fissure has not yet been completely investigated, but in the foetus it develops in three parts, an anterior, a middle and a posterior. In most cases these three unite together in the adult to form the long calloso-marginal sulcus. Later these have been renames respectively the rostral sulcus (anterior), the calloso-marginal sulcus (in the middle) and the post-limbic sulcus (posterior). This last sulcus is absent in the lower apes (see Elliot Smith's figures, Quain's "Anatomy", Catalogue of the Museum of the Roy. Coll. of Surg. Eng., etc.). It develops late in the foetal brain, about the beginning of the seventh month (see Cunningham, and also Retzius). In this microcephalic brain it is present, but small and shallow. It would appear as if it were in process of formation when the arrest in development occurred, and as this sulcus is absent in the lower ape brain, it did not develop any further. The middle, or calloso-marginal sulcus is well developed and most distinctly simian in appearance. It passes gradually on to the supero-mesial border in a manner very similar to that seen in the Gibbon (Fig. 285, Quain's "Anatomy", 1908), but differs from the ape sulcus in the respect that there passes off from it about 25 mm. from its posterior extremity a single furrow which runs vertically upwards, and this forms the posterior border of the paracentral lobule which is, in consequence, triangular in outline. And further this posterior furrow is only shallow compared with the calloso-marginal sulcus itself. It would thus appear as if we are again dealing here with both a simian and a foetal characteristic. And again we have the explanation in the foetal condition/first developing and then being almost lost in the superposed ape condition. The appearance of the rostral sulcus is most ape-like, and in fact the great resemblance of this region to the ape brain is well seen in the two following figures, the ape brain being that of the gibbon from p.298 of Quain's "Anatomy", 1908. I have chosen this brain in particular because of the great resemblance which it bears to the brain of Robert Lindsay.



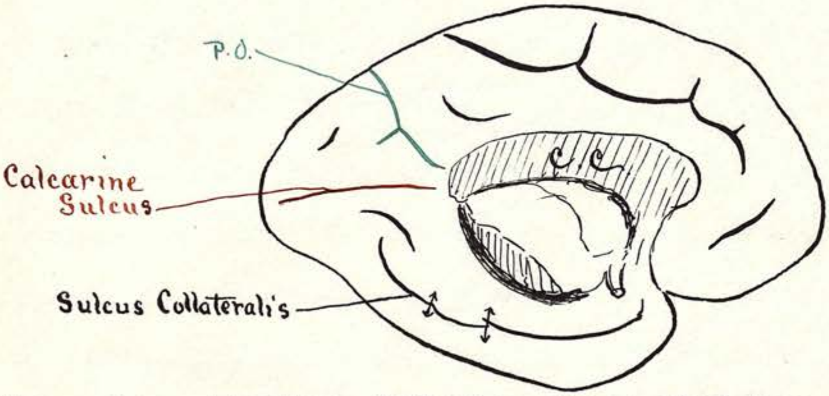
Rob. Lindsay.



GIBBON.

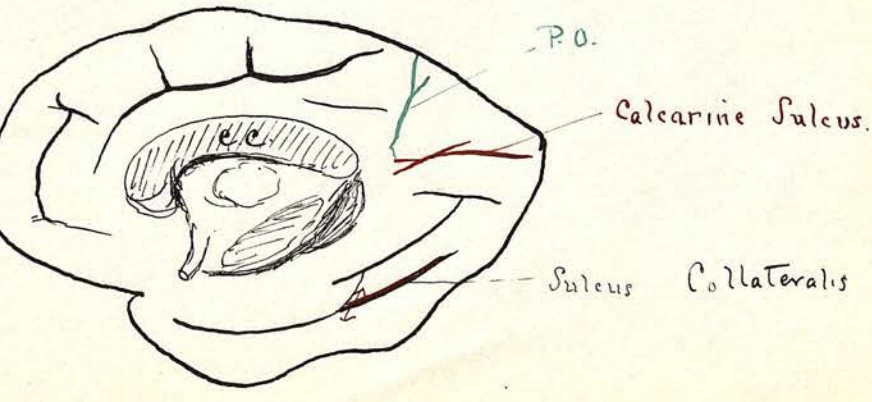
The Collateral Sulcus :

The collateral sulcus in both hemispheres is well developed. In the left hemisphere it is formed in three parts which are separate from each other. In the right hemisphere these three parts have all united to form a continuous furrow. In the following figure the condition is well shown. The anterior part passes directly into a deep transverse fissure which probably represents

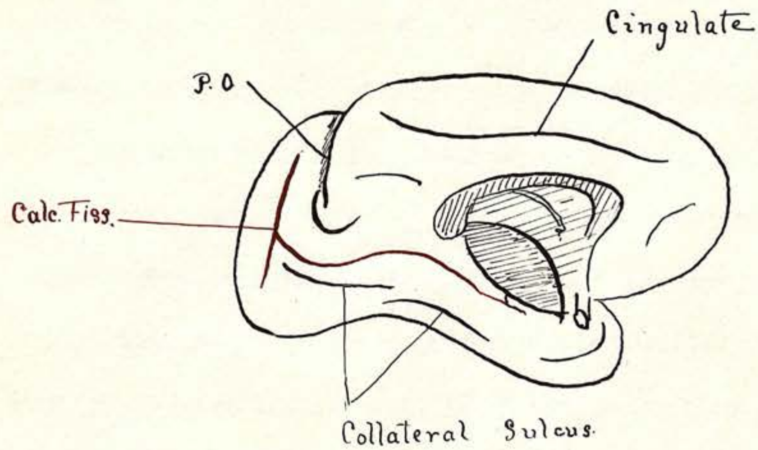


the sulcus limitans inferior areae striatae. The middle sulcus is marked in red and is separated by a deep gyrus (at the point where I have placed the arrow) from its posterior part. The posterior part runs straight towards the temporal pole, but ends on the mesial side.

On the left hemisphere there is only one long continuous furrow which is divided into three by the deep gyri which I have marked by arrows in the following figure.



It does not arise directly from the sulcus limitans inferior areae striatae, but is separated from it by a distance of 5 mm. The sulcus collateralis develops in the foetus in three parts which ultimately unite to form a continuous fissure. In this brain, therefore, the foetal condition is to some extent present, but some other cause than just a persistance of the foetal condition is found, since there is a quite unusually large hippocampal gyrus with a very small and diminutive uncus. This condition is found in the lower ape brain, and is a simian characteristic, and the deep collateral sulcus which is formed in consequence of this is, therefore, also a simian characteristic and bears a very close resemblance to the condition of the sulcus collateralis found in the capuchin monkey (Cebus), (See Fig. 279, p. 294, Quain's "Anatomy", 1908).



General Remarks on the Brain of Robert Lindsay.

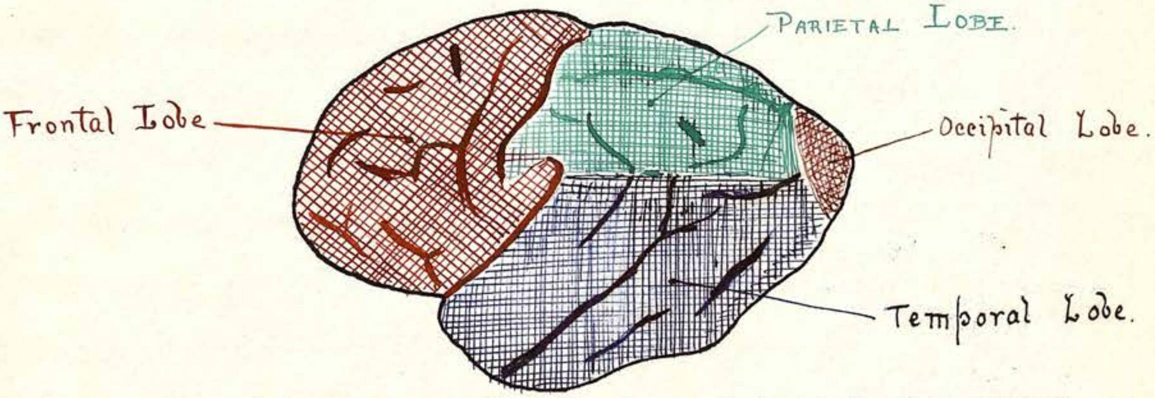
I have now shown that in the brain of Robert Lindsay a remarkable series of changes have occurred, which have resulted in the formation of a brain of a very small size, with very simply arranged fissures and convolutions. I have described these fissures and convolutions fully, and have shown as a result that they do not bear any direct or close resemblance to a merely simply convoluted human brain. The arrangement of the fissures themselves as well as their relations to each other are of such a nature as to show quite conclusively that the condition is obviously not just a simply convoluted adult human brain. When this point was first recognised it was then pointed out that the condition was an "atavism". This word was first used by Vogt, who considered that a mere arrest of development might constitute an "atavism". By such an arrest an embryonic condition might be stereotyped on the surface of the fully formed brain. But a mere arrest of development cannot possibly account for the condition here present, because we have here present furrows which are never found in the normal developing brain. The fronto-orbital sulcus, the absence of the anterior calcarine sulcus, the sulcus postcentralis inferior, and many other sulci show a condition which is never found at any stage in the foetal brain. We find also the presence of embryonic sulci close to and side by side with fully developed sulci, as e.g., in the frontal lobe.

And the condition is not one of a direct resemblance to the ape brain, because we find arrangements present which are not found on any ape brain; e.g., the position of the fissure of Rolando and the fissure of Sylvius in the same straight line on the right hemisphere is not found on any ape brain, neither is the fissure of Rolando characterised by the presence of a terminal bifurcation at its lower extremity in any low ape brain.

The view that the condition is a reversion to a "stem-form" is also not quite correct, because of the curious mixture of foetal and simian characters side by side, the presence of which is quite inconsistent with our knowledge of the development of the foetal brain and of the low and high ape brains.

But the point to which I specially wish to draw attention is this : on the microcephalic brain there are found conditions which are found on it alone. They are not present in the adult human brain, the foetal or the ape brain, nor do they fit into any place in the natural evolution which has occurred from the ape type to the human type. They are characteristic of the microcephalic brain alone and are only found on it. Of these I can instance the fissures of Rolando and Sylvius being in the same straight line, the disappearance of the postcentral gyrus, the reduction and diminution in the occipital region, quite out of proportion to the rest of the brain, etc. No mere "reversion" to an ape type can cause such changes as these. And as it is upon these changes that I wish to lay such stress, it is evident that the condition found in one microcephalic brain, however typical, is scarcely sufficient foundation upon which to base such far-reaching deductions. I have therefore made a complete and careful study of a series of typical true microcephalic brains in order to determine whether these particular points are always present, and what variations they may show. Having once determined all these points carefully, we are in the position of having a definite foundation on which to base subsequent deductions. I shall therefore leave my full account of the cause and nature of the changes at present, until I have completed the above examination and shall content myself with stating that these characteristics which I have mentioned as being found only on the microcephalic brain (and being typical of it alone) are due to mechanical disturbances which have occurred in consequence of an arrest in the normal development of the brain somewhere about the third or fourth month. From this period onwards the development has proceeded along a less highly specialised path, and has resulted in the production of a brain which bears a great resemblance to those found in the lower apes, the similarity, however, not being exactly accurate since the above mentioned points are not found in lower ape brains. But we obtain a complete explanation of all the points found in the microcephalic brain by regarding it as the necessary result of the superposition of a simple ape-like type of brain upon a normal three or four months' foetal brain. The full reasons for coming to such a conclusion will be discussed later after I have determined the importance and significance of the various changes, from the examination of a large number of typical true microcephalic brains. In the meantime I shall conclude this description of the brain of Robert Lindsay by a general account of the condition present.

This brain is greatly reduced in size and the different parts have not suffered equally. The frontal lobe is least affected, then the temporal. This lobe is mostly reduced in size at the temporal pole. The greatest reduction is in the parietal and occipital areas. This latter region has specially suffered and in consequence the occipital pole does not cover the cerebellum to any great extent. If I divide the brain into its four regions (frontal, parietal, occipital and temporal) after the manner described by Cunningham (p. 514, Textbook of Anatomy) a very striking result is got. First, the frontal lobe is slightly reduced in size, but not to any conspicuous extent. The most striking feature is the great reduction in the occipital region and the great increase in breadth of the temporal region, while the parietal region, though reduced, has



not suffered to any great extent. But it is the great reduction of the occipital lobe which is so conspicuous, and this is associated with the changes which I have just described in connection with the visual area. The greatly increased width of the temporal region is also most pronounced and is associated with the rotation forwards of the Sylvian fissure. Because, although the Sylvian fissure has rotated forwards, the infero-lateral margin has not correspondingly altered, and thus the region between the fissure of Sylvius and the infero-lateral margin is relatively increased. This point is very important. The fissure of Sylvius rotates forwards in consequence of changes in the fissure of Rolando (to be discussed later), and this occurs before the opercula have begun to form, and it would appear that the mechanical derangement following such a forward rotation would influence the island of Reil and the opercula covering it. The absence of the frontal and orbital opercula is not due to any mechanical disturbance; it is purely a simian characteristic. But as the result of this increase in the extent of the temporal region, the temporal operculum will not grow forward over the Island of Reil, since there is so much extra space behind it ; it will simply extend downwards since this is the path of least resistance. And it would appear that the complete forward rotation which the fissure of Sylvius has undergone has affected the island of Reil considerably. This is a purely mechanical result, and even if the opercula were formed normally they would be greatly reduced in size corresponding to this reduced island of

Reil. I shall later show that these fibres which arise from these opercula and pass down the crura cerebri are extremely feebly medullated.

The fissure of Rolando is easily recognised. It is short, shallow, with smooth boundary walls and no annectant gyri. It appears to have developed in one part and represents a purely simian characteristic.

The fronto-orbital sulcus is very well marked and in both hemispheres there is an incipient orbital operculum.

The frontal lobe is characterised by a most typical T-shaped sulcus consisting of the sulcus praecentralis superior and inferior, and the inferior frontal. The great prominence of these three sulci is a most characteristic simian resenblance. The poorly developed and separated elements of the superior frontal sulcus are clearly foetal.

The parietal lobe is characterised by its deeply marked intraparietal sulcus, due to a great increase in the rate of development of this area. This increase has resulted in the production of this simple, continuous, and most ape-like sulcus, while the sulcus postcentralis inferior has been pushed forward until it has coincided with the fissure of Rolando and the ascending gyrus has disappeared.

The occipital region is greatly reduced, this reduction affecting chiefly the outer surface. The mesial surface bears a most characteristic resemblance to the ape brain ; the gyrus cunei rises to the surface; there is no anterior calcarine sulcus, and the posterior calcarine sulcus is quite unusually well developed. The sulcus limitans praecunei and the sulcus paracalcarinus are poorly developed, and the arcus intercuneatus comes to the surface. In the other hemisphere the sulcus limitans praecunei is absent, and the incisura parieto-occipitalis passes right down to the lower end of the parieto-occipital fossa.

The temporal region is greatly altered, chiefly in its increased width. The upper part of the first temporal operculum has rotated forward with the fissure of Sylvius, and has ultimately formed the posterior arm of the terminal bifurcation of the fissure of Sylvius. The long sulcus which passes from the temporal pole to the centre of the intraparietal operculum is thus composed of two fissures, the upper part of the second temporal sulcus and the lower part of the first temporal. This change is an important one. It is due to the attempt to reproduce the simian condition, as this is the fissure which is so pronounced in the temporal region in the lower ape brain. The lower part of the second temporal fissure is present in both hemispheres.

The calloso-marginal sulcus is divided into three elements in both hemispheres, and presents marked simian resemblances, as does also the collateral sulcus.

I shall now proceed to examine a series of those microcephalic brains already published and illustrated with sufficient accuracy to allow of exact observations being made from them ; after which I propose to discuss this question in full.

THE

COMPARATIVE MORPHOLOGY of MICROCEPHALIC BRAINS.

It is the usual custom on describing the brain, to begin with an account of the general outline, shape and other characterists of the brain, as well as a list of the principal measurements. The shape of the microcephalic brain differs very greatly from the normal, the reduction in size affecting different parts to different degrees, and in order that we may be able to appreciate to the full what is the significence of these various changes, I propose to first make a study of these separate areas by themselves. After I have done this, and discovered what fissures are to be considered as prominent landmarks, we will be in a position to realise to what extent each area is relatively increased or diminished in size and what amount of variation is found in the different brains, and thus establish upon a sure foundation the fundamental changes which have occurred in this condition. It is also of no great profit to compare a list of measurements of the size of the frontal lobe by comparing the distance from the upper end of the fissure of Rolando to the most anterior part of the brain, until we fully realise the amount of change in the position of the Rolandic fissure, because we know that this fissure is subject to great alterations in position in the microcephalic idiot. I therefore propose to begin this study by first of all determining what fissures are found constsntly on the microcephalic brain; what displacements and variations these fissures have undergone, and thus be in a position to know on what factors we may rely in comparing the complete microcephalic brain with the human adult, foetal and ape-brain.

Having once discovered what are the constant features found on the microcephalic brain, I shall try to point out what is the nature of the change which has resulted in such an arrangement of the fissures and convolutions. Then I shall discuss the question of the cause of microcephaly, and finally shall try to show that the view expressed by Cunningham in his monograph on this subject (p. 290) is correct;- namely, that true microcephaly forms a natural group, outside the domain of pathology, and comprises brains which present certain common morphological features, and a certain more or less easily distinguished uniformity of type.

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In studying the comparative morphology of the microcephalic idiot brain, I had at first intended to take up each individual fissure in turn and trace its characteristic features through all those cases on record which would be placed in the group defined by Giacomini and Cunningham as "true microcephaly". I very soon found, however, that this was impossible, as, on making a careful comparative study of these fissures from the point of view of the present stage of our knowledge of cerebral morphology, it became evident that great confusion has existed in the minds of different authors as to the true identification of the various sulci. A fissure, which is identified as being a certain fissure by one author, is considered by another author as an entirely different fissure, and yet, on comparing these two fissures side by side it is quite clear that they are really the same fissure. This is very well seen in the confusion which exists in the various monographs as regards which fissure represents the Fissure of Rolando, this name having been applied to a large number of different fissures. The fissure which it has been most often ~~been~~ mistaken for is the praecentral fissure, and this mistake is to some extent a natural one. It has been shown by Prof. Cunningham that one of the features of the microcephalic brain is the extremely poor development of the fissure of Rolando, and as the praecentral fisure is very strongly developed and often displaced backwards it comes to occupy the position usually taken by the fissure of Rolando, and thus has frequently been mistaken for it. It is therefore very important that, before making a comparison between the different brains, that we should identify the fissures accurately.

But there is another point of great importance, which I also wish to emphasise; namely;- that although the position, character and appearance of the fissures are very much altered with regard to their appearance in the human brain, they are also very considerably altered in their relation to neighbouring sulci, in some cases two or more sulci which are separate in the human brain (and also in the ape-brain) appear to have united in the microcephalic, so that although the appearance is that of a single fissure, we are really dealing with two fissures occupying the same position, and this point can only be determined by making an examination of a large number of such microcephalic brains, when we find in some that the union is not quite complete, thus giving an intermediate condition which shows us the manner in which this union has taken place. As an example of this latter condition I can point to the union of the fissure of Rolando and the post-central sulcus a question which I shall fully discuss in the next few pages.

I therefore propose, in examining the comparative morphology of the microcephalic brain to examine the different sulci in groups which form a more or less natural division, and of these the first which I propose to take up comprises four fissures;-

The fissure of Rolando,
The fissure of Sylvius,
The praecentral fissure, and
The post-central fissure.

I shall discuss each fissure more or less independently, partic--ularly in regard to its special characteristics and its relation to neighbouring sulci; after which, I shall take up its relation to the normal human adult brain, to the human foetus, and to the different ape brains, ~~after which~~ and then I shall try to point out the nature of the change which has resulted in such a marked deviation from the normal condition.

<u>The fissure of Rolando</u> in the microcephalic brain has been very fully described by Prof. Cunningham in his monograph upon the brains of 'Fred' and 'Joe', and is characterised by three principal features;-

First:- It is very much reduced in length, and consists usually of a short straight furrow;

Second;-It is very shallow and of the same depth throughout all its extent;

Third;- There are never any signs of any deep annectant gyri.

It therefore presents a condition which resembles most that found in the lower apes. In man the fissure of Rolando developes in two parts, an upper and a lower, and when these ultimately meet, the point of union is invariably marked by one or more deep annectant gyri (Cunningham, A. W. Campbell, etc). The result of this is that the fissure of Rolando is very well marked in the human brain. As these deep annectant gyri are also present in the anthropoid apes it is probable that there ~~the~~ fissure of Rolando also developes in two parts ~~also~~; but in the lower apes there is no trace whatever of a deep gyrus and thus probably the fissure developes in only one part, while in some of the lower apes e.g. Nyctipithecus (Mus. of Roy. Col. of Surg. of Eng. Catalogue; Vol. II. p. 391.) it is absent altogether. I have been unable to find any description of this fissure in a typical microcephalic brain in which any deep gyri are present; but the great reduction in the size of this fissure

Right Hemisphere of Robert Lindsay.

in all microcephalic brains has not been fully recognised since in many cases the well developed praecentral fissure has been mistaken for the fissure of Rolando. (See later).

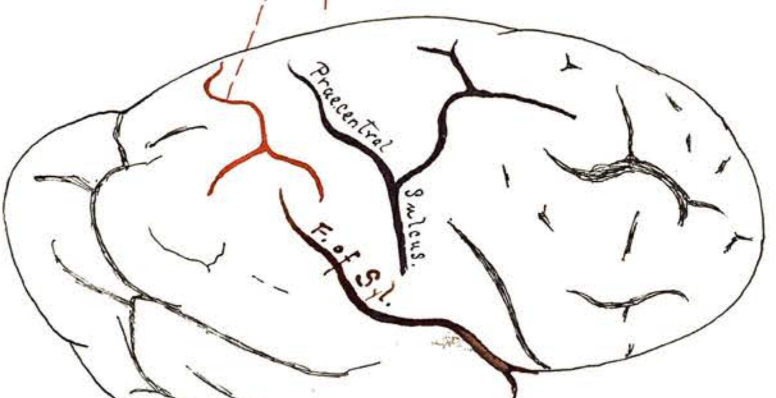
But, apart from the three above mentioned characteristics of the fissure of Rolando in the microcephalic brain, there are two other points to which I specially wish to draw attention, and which up till now have been completely overlooked, namely;-

First;- The fissure of Rolando and the fissure of Sylvius are usually situated in the same straight line; +

Second;- The lower end of the fissure of Rolando ends in a terminal bifurcation, between the two arms of which, the posterior end of the fissure of Sylvius is situated. (See fig. at foot of page).

I now propose to examine a series of microcephalic brains in order to demonstrate the accuracy of these two statements, and to determine why they are not present in some cases. To do so I shall first locate beyond all doubt the true fissure of Rolando in each case, then discuss and its relation to the surrounding sulci.

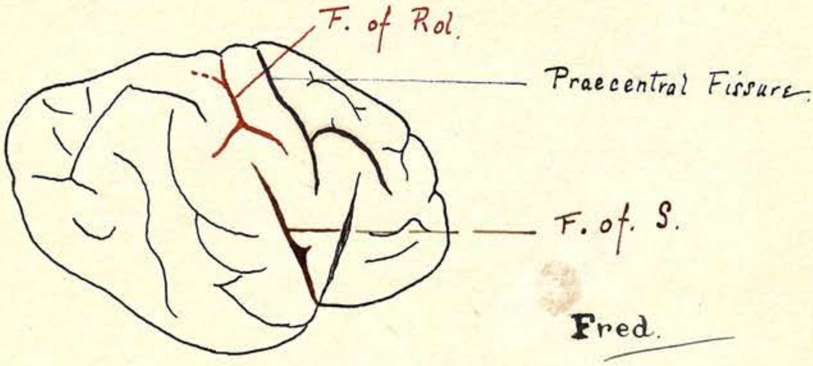
In the brain of Robert Lindsay, as I have already shown, there is no difficulty in deciding which is the true fissure of Rolando. The praecentral fissure is also very well marked and shows a condition which is very typical of the microcephalic brain, namely the shape of the letter Y, a point which is of great service in identifying this fissure in other microcephalic brains. In the accompanying figure I have coloured the fissure of Rolando red, the praecentral fissure blue, and the fissure of Sylvius brown. In this case it will be noticed that the fissures of Rolando and Sylvius are not quite in the same straight line, a point which I shall discuss shortly; but, it will also be noted



Joe.

that in both hemispheres the lower end of the central fissure bifurcates, and the upturned end of the fissure of Sylvius lies between these two arms.

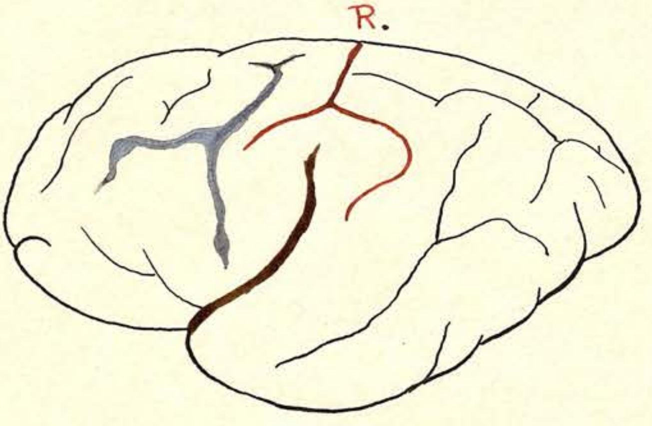
If we now examine the brains of 'Fred' and 'Joe', as described by Prof. Cunningham in his monograph, a most typical appearance of these two fissures will be at once seen. I have reproduced here a tracing of the right cerebral hemisphere of 'Fred', and it will be noticed that the fissure of Rolando is short and straight, that it ends in a terminal bifurcation, and that it is in identically the same straight line as the fissure of Sylvius.



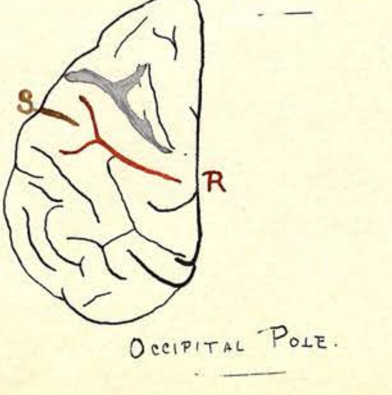
Fred.

In the right cerebral hemisphere of 'Joe' we are probably dealing with a case in which, owing to the great prominence of the praecentral fissure, it has probably been mistaken for the fissure of Rolando, which is really the small fissure lying posterior to it, and which exhibits all the characters of this fissure, namely, it is short, ends in a terminal bifurcation, and is in approximately the same straight line as the fissure of Sylvius; while the fissure situated anterior to it shows the typical Y shaped appearance of the praecentral sulcus.

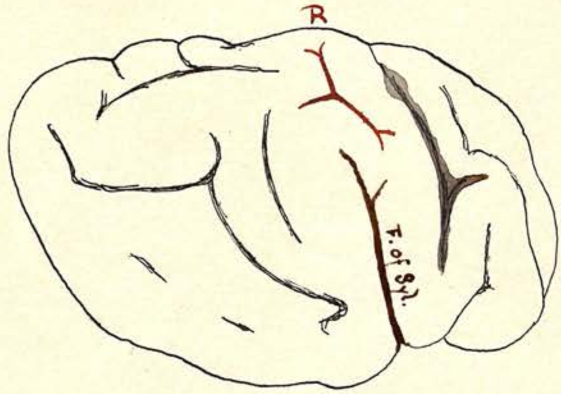
In the brain described by Macnamara and Burne in the Jour. of Anat. and Physiol, I903, p. 260 there is no difficulty in deciding which is the true fissure of Rolando, and here also it will be noticed to be short and straight, to end in a terminal bifurcation and to lie in approximately the same straight line as the fissure of Sylvius.



In the brain described by Marshall and Gore (Anthrop. Rev. May, I863) a very typical fissure of Rolando is seen on the left side, the terminal bifurcation being very well marked, and the end of the fissure of Sylvius will be seen just between the two arms.

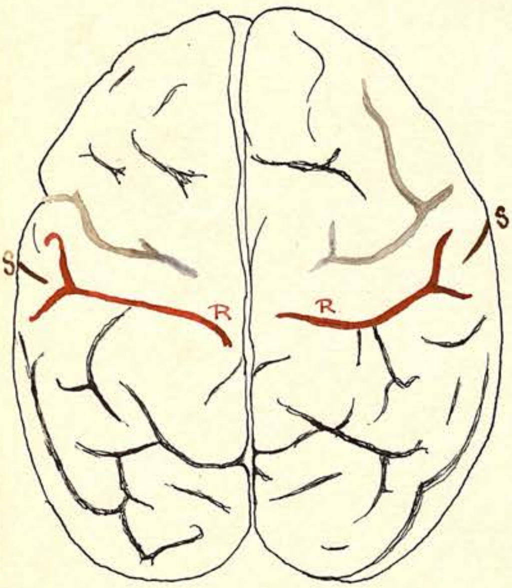


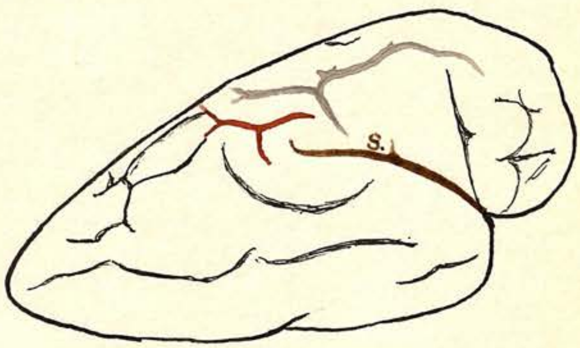
In the extensive monograph by Giacomini (Cervelli dei Microcefali) there are figured nine brains of which only three are to be considered as true microcephalic brains, the others exhibiting at a glance most extensive pathological changes which at once remove them from the group of true microcephaly. In all of these three brains, Giacomini had mistaken the praecentral fissure for the fissure of Rolando. In the accompanying figures which I have traced from his diagrams, I have renamed these fissures accurately In his figure of the brain of Rubiolio Modesta, the condition is most typical; the fissure of Rolando is short and straight, ends in a terminal bifurcation, and is in the same straight line as the fissure of Sylvius; while the praecentral fissure is deep, strongly marked and well developed.



Rubiolio Modestá.

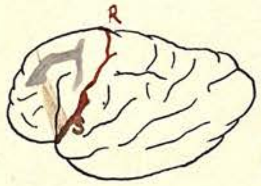
In the monograph by Bischoff upon the brain of Helene Becker, there will be found a very clear description of the microcephalic brain, accompanied by a series of most beautiful illustrations, which are so clear and distinct that it is almost as easy to distinguish the various sulci as if we had the brain itself in our hands. And in this brain, Bischoff has also mistaken the praecentral fissure for the fissure of Rolando. This has been pointed out by Prof. Cunningham in his memoir (p. 309) and I think the accompanying diagram brings this point out very distinctly. It will be noticed that the fissure of Rolando is short and poorly developed, that it ends in a terminal bifurca--cation, and that it is in the same straight line as the fissure of Sylvius.





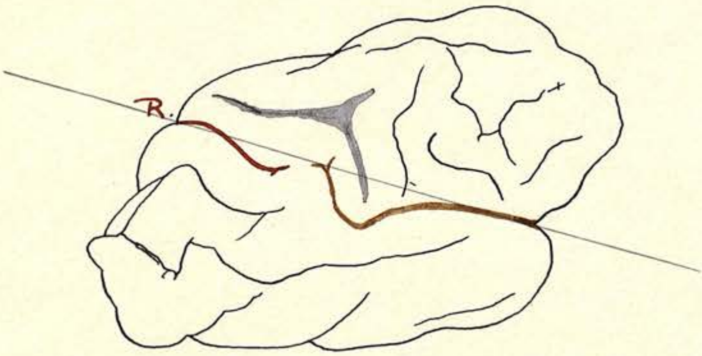
Marchand, in his large monograph (1891), publishes the

account of three microcephalic brains with illustrations, and also gives illustration from several of the other micro--cephalic brains which had been previously published. These are unfortunately not very clearly represented, and thus it is not very easy to identify the various fissures accurately.
In his Fig. 6, however, there appears to be represented a condition which I have never discovered in any other microcephalic brain, namely, not only are the fissures of Rolando and of Sylvius in the same straight line, but they appear to have become united to form a single long fissure. His figure is however, rather too wanting in preciseness to allow me to state definitely that this is the case.



(?).

In one of the most recent articles on this subject by Mingazzini in the Monatsch. Psych. u. Neur. 1900, p. 436, I notice that, ~~al~~ although the praecentral furrow is unusually well marked, and situated even further back than is often the case, and, in consequence the fissure of Rolando is pushed very far back, still he has quite accurately recognised it and not mistaken it for the praecentral fissure. In this case the fissure of Rolando is short and poorly developed; and although it does not end in a terminal bifurcation (for reasons I shall later describe) still it is in approximately the same straight line as the fissure of Roland only, owing to the downward prolongation of the praecentral fissure, there has resulted a small kink in the posterior part of the fissure of Sylvius.



I think that I have demonstrated a sufficient number of microcephalic brains to show that this point, namely, that the fissure of Rolando and the fissure of Sylvius are very often situated in the same straight line, and I now wish to discuss what are the conditions which have been at work and have produced such a result.

In order to allow such a result to take place it is obvious that the united length of the fissure of Rolando and the fissure of Sylvius must be shorter that the ~~[illegible]~~-length of the hemisphere from the upper point of the fissure of Rolando to the lower point of the fissure of Sylvius, as if this were not so then the upper end of the one and the lower end of the other would meet. This arrangement is not found in any fully developed human brain; there both fissures are very long and if they were to be arranged in one straight line more than three-quarters of each would coincide. In the human foetus the fissure of Rolando does not appear until the last week of the fifth or the beginning or middle of the sixth month, (Cunningham Memoir, 1892); and by this time the fissure of Sylvius forms very nearly a right angle with it. It thus is apparent that this condition which is to be found in the microcephalic brain finds no resemblance in the human brain at any period of its development. But, it also finds no resemblance to any ape brain; I am aware of no ape brain in which such a condition is present and thus it cannot be looked upon as a simian character. It is, in fact, a character which is typical of the microcephalic brain alone, and is not to be looked upon as being directly a human, foetal or simian character. It is thus also very clear that the term 'atavism' as used by Vogt, cannot be applied to this condition. Vogt considered that "a simple arrest of development necessarily involved an atavistic condition". Cunningham pointed out that this was a conclusion he could not accept, and showed from his investigations that the condition was not one of simple arrest of development "so that a transitory embryonic condition becomes stereotyped". I most strongly agree with this view, and I think that if we consider the condition from the point of view which I propose to look at it, as well as from the point of view from which the question has been approached by Prof. Cunningham in his memoir, we get conclusive proof that the condition cannot possibly be considered as simply an arrest of development, with subsequent alterations depending upon this.

As we thus cannot look upon this question as a direct reversion to any ape type or as a developmental arrest we must search for some other cause, and the first fact to which I wish to draw attention is the following;- if we have two bodies which are attracted to each other and at the same time are in a state of stress in regard to the surrounding medium, these two bodies will tend to arrange themselves in the position of least resistance, and in the case of two elongated bodies this will be a straight line; and, therefore, we can look upon this arrangement of the fissure or Rolando and the fissure of Sylvius as the result of some mechanical interference in the growth of the hemisphere, or of the fissures themselves, or of both, which has resulted in their taking up the line of least resistance. Why these two fissures should be specially affected is because they are the first to appear in the human foetus. (I think there can be no doubt that the 'precursor of the praecentral fissure' is due to an indentation of the surface of the brain by the anterior margin of the parietal bone.) We have thus got a step forward, and now must discover the cause which has produced such a mechanical disturbance in the growth of the brain. Of all the views which have been put forward to explain the condition of microcephaly, that of Prof. Cunningham is unquestionably the best, and, furthermore, is based upon accurate scientific facts. There are, however, a certain number of facts which it is rather difficult to explain under this theory, and I propose here to put forward a new theory which explains all the known fact in a remarkably successful manner. It must, however, be clearly understood that this theory is only a modification of that of Prof. Cunningham, and which I am enabled to put forth owing to the great advances which have been made in our knowledge in recent years. I shall, thus, discuss somewhat fully Prof. Cunningham's view of this condition.

Cunningham considers that the condition is the result of an 'atavism,' but he uses the word with quite a different meaning than that of Vogt. He does not consider that a "simple arrest of development" can constitute an atavism. "In a simple arrest of development a transitory embryonic condition becomes stereo--typed, as it were, but this does not necessarily imply that the phase which is produced is one which at any previous time in the phylogenetic evolution of the individual was character--istic of the stem-form. Something more is required to constitute an atavism. It is necessary that certain of those ancestral features which are omitted in the ordinary course of development should be reproduced, or that certain of those parts of the phylogenetic history, which in the ontogeny of the individual have become blurred or abbreviated, should reappear in a distinct and intelligible manner. This is what we believe to have taken place in the case of the cerebral surface of the two micro--cephalic brains, Fred and Joe. Whether either one or other repeats in its totality the convolutionary pattern which was distinctive of any particular period in the evolution of the stem form, it is impossible to say, but we are rather inclined to think that neither of them does. Certainly we may exclude the brain of Joe from such a generalization. The case is differ--ent, however, with the brain of Fred. The convolutionary arrangement is more ape-like than human, and it is so consistent in its pattern throughout the whole cerebral surface that we cannot shut our eyes to the possibility that in it we may have a tolerably faithful reproduction of the gyri and sulci which at one time were characteristic of an early stem-form of man."

In short, Cunningham considers that the microcephalic brain is a brain which has become arrested in its devel--opment about the third or fourth month. Up till this date the development has proceeded along the lines which would, under normal circumstances, have resulted in a typical, full-sized, normal human brain. But about the third month some change has occured which has altered the normal growth of the brain and caused it to proceed along a less highly specialised path resulting in a brain which is greatly reduced in size with a simple convolutionary arrangement, which closely resembles that found in various apes today, and which is considered by Cunningham to represent a stem-form, which, at some time in the ancestral history of man, was characteristic of the human brain.

This view of Cunningham's is a far closer approach to the truth than any other view which has yet been put forth, but it will be noticed that even it will not explain all the facts completely, and this is pointed out by Cunningham himself in regard to the brain of 'Joe', and he also states that "he is rather inclined to think that neither brain repeats in its totality the convolutionary pattern which was distinctive of any particular period in the evolution of the stem form".

But let us now look at the matter from a new point of view. Up till three months the microcephalic brain has developed normally; its normal course of development has then been altered and it has resulted in the production of a much smaller brain which bears a most remarkable resemblance to the ape brain. It is, in fact, obvious that the view of Cunningham regarding the condition as an "atavism" is correct, and that we are dealing with a return to some ancestral period in the phylogenetic evolution of the brain. But here we come to the crux of the whole question. Such a 'stem-form' is of a smaller size than the fully developed human brain, and, therefore, when this alteration in the development of the brain occurs, it results in the superposition of a smaller type of brain upon the foetal brain typical of an embryonic condition corresponding to a fully sized human brain. In other words, we are dealing with <u>the superposition of the ape-brain upon the foetal brain;</u> and thus it is at once clear, when we regard the question from this point of view, why it is that the microcephalic brain does not resemble the human, the foetal or the ape brain. And it is also clear why it is that we find both foetal and ape characters upon the surface; if the alteration in the development occurs at the beginning of the third month then the ape characters will be in the ascendency, if the alteration occurs at the end of the fourth month then the foetal type will be more prominent. And that this is so has been very clearly demonstrated by Cunningham since he has pointed out that in Joe the foetal type is most marked, while in the brain of Fred the ape type is the more conspicuous. (Why I limit the change to the third and fourth months will be fully discussed further on in this paper). And we have here the explanation why there is to be found on the microcephalic brain, features which are absent both in the foetal and in the ape-brain, since as the result of the superposition of the ape type upon the foetal certain mechanical disturbances have occured which have necessitated a rearrangement of the con--volutions and fissures in relation to each other, resulting in their taking up in each case the line of least resistance. In attempting to interpret the arrangement of the fissures and convolutions in the microcephalic brain, I propose to discuss the question from four points of view;-

First;- their resemblance to the human adult brain,
Second;- " " " " " Foetal brain;
Third;- " " " " various ape brains; and
Fourth;- " " " " condition which would result from the superposition of the ape brain upon the foetal, and

it will be found that in almost every case we find that the arrangement of the fissures and convolutions upon the micro--cephalic brain is practically identically the same as would result under ~~such~~ these latter conditions.

We are now in a position to take up the question of the arrangement of the fissure of Rolando and the fissure of Sylvius in one straight line, which I have already pointed out represents the line of least resistance between two forces. The first point to which I wish to draw attention is that as the result of this alteration in the normal development of the brain with the subsequent superposition of a smaller sized ape-like brain upon that of a normal sized foetal brain, ~~and~~

~~as a result of this~~, the fissures and convolutions which now form on the brain will be smaller than those which would have formed in the normal course of development, and this in itself would be sufficient to cause some mechanical disturbance in the arrangement of these fissures. But the alterations which have taken place in the different fissures are far greater than can simply be accounted by the formation of smaller fissures corresponding to the smaller sized brain. The fissure in Rolando in particular, has undergone a great change; in the human foetus it developes in two separate parts, the lower of which appears about the last week of the fifth month, the upper and smaller one, a few weeks later. Later these unite. In the three or four months foetus there is no sign of a fissure of Rolando; but the fissures of the brain are due to unequal growth of the cortex, and the cortex in the microcephalic brain at this early period will be arranged in the normal manner which will later result in the appearance of two furrows in the manner described by Prof. Cunningham (Cunningham Memoir). But in the lower apes, the fissure of Rolando is small, short and shows a complete absence of any deep gyri; it has, apparently developed in one piece. As I have already mentioned, the fissure of Rolando in the microcephale very closely resembles that in the lower ape, it is short, small, of uniform depth and there is no deep gyrus. It is thus apparent that a great change must have occured in the fissure of Rolando and frontal con--volution about the third month. The cortex which was growing presumably in the normal manner, has been so affected that its development has been completely altered; instead of developing in two parts, it has developed in one; the upper part evidently having disappeared. When the fissure later does develop, it is, therefore, greatly reduced in size, as also must be the cortex of the ascending frontal convolution. As a result there is a diminution in the grey matter towards the upper end of the fissure of Rolando, and the result of such a diminution must be a mechanical disturbance of the other fissures present on the external side of the hemispheres. But at this period there is only one fissure present, and that is the fissure of Sylvius, and this, in order to compensate for the diminution in the cortex at the upper end of the fissure of Rolando and its subsequent passage upwards, will be subjected to a mechanical stress, which will tend to cause it to move forwards the area where this force is situated, namely the lower end of the fissure of Rolando. But the fissure of Sylvius will also be affected by such a change, and the result will probably be a shortening of its length in proportion to the reduced size of the superposed smaller brain. At the same time we also know (Cunningham's Memoir, pp. 133, 135) that the Sylvian angle is considerably reduced in the apes.

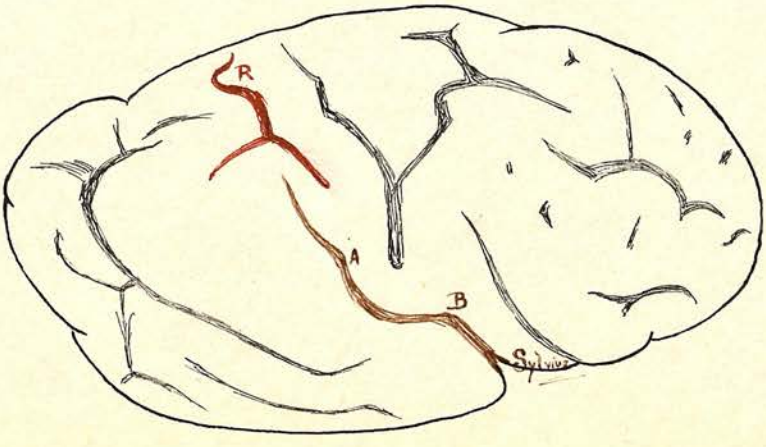
	Average Angle
Adult man	67. 8
Full-time foetus	62. 1
$7\frac{1}{2}$ months' foetus	61. 5
Chimpanzee	54. 5
Orang	55
Cebus	54. 1

Baboon	48. 6
Macaque	46. 5
Hamadryas	44
(Fred	52 (46° and 60°)
Joe	53)

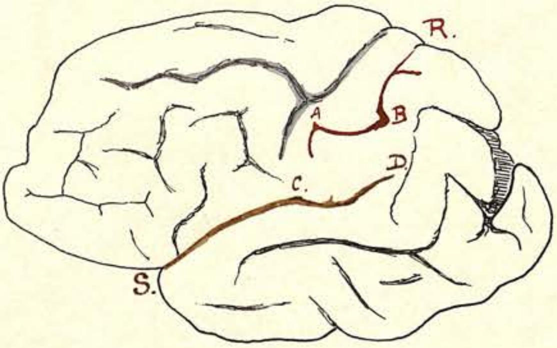
This table shows that the lower we descend among the apes, the less the Sylvian fissure becomes. Thus when we find the diminished Sylvian angle in the microcephalic brain we know that there must have been a rotation upwards of the Sylvian fissure, and it is significant that though a diminished Sylvian angle is also characteristic of the human foetus, the diminution in the microcephalic brain is less even than this, so that this diminution in the Sylvian angle is not purely a foetal characteristic. There are, therefore, two factors at work here : the diminution in length and in the angle of the Sylvian fissure, and at the same time a great shortening and alteration in the Fissure of Rolando. These two together, and especially the last factor cause a mechanical disturbance, which, since the anterior end of the fissure of Sylvius is fixed, must result in the posterior end rotating round until it reaches the point of least resistance, that is, opposite the lower end of the fissure of Rolando, In other words, when the fissure of Rolando and the fissure of Sylvius are in the same straight line.

But the fissure of Sylvius and the fissure of Rolando are not always situated in the same straight line, and I now propose to discuss these cases fully. It must be at once evident that it is not possible for these two fissures to arrange themselves in one straight line, if they are of such a length that the two ends overlap. I have pointed out that the chief factor is the rotation forwards of the fissure of Sylvius consequent upon a reduction in length of the fissure of Rolando.

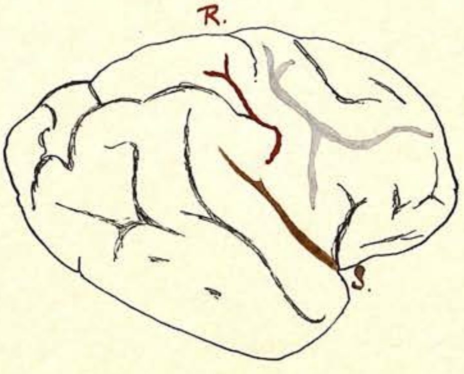
That this is so, is well seen in the right hemisphere of 'Joe'. Here the fissure of Sylvius, as it rotated forwards, was prevented from reaching the same straight line as the fissure of Rolando, by the prominent lower end of the praecentral fissure. As a result of this the anterior part of the fissure, which has been unaffected by the praecentral sulcus, lies in the same line as the fissure of Rolando, while the posterior end has been prevented from reaching this position by the lower end of the praecentral fissure, which has thus caused a bend in the fissure of Sylvius just opposite this point (AB in the accompanying fig.)



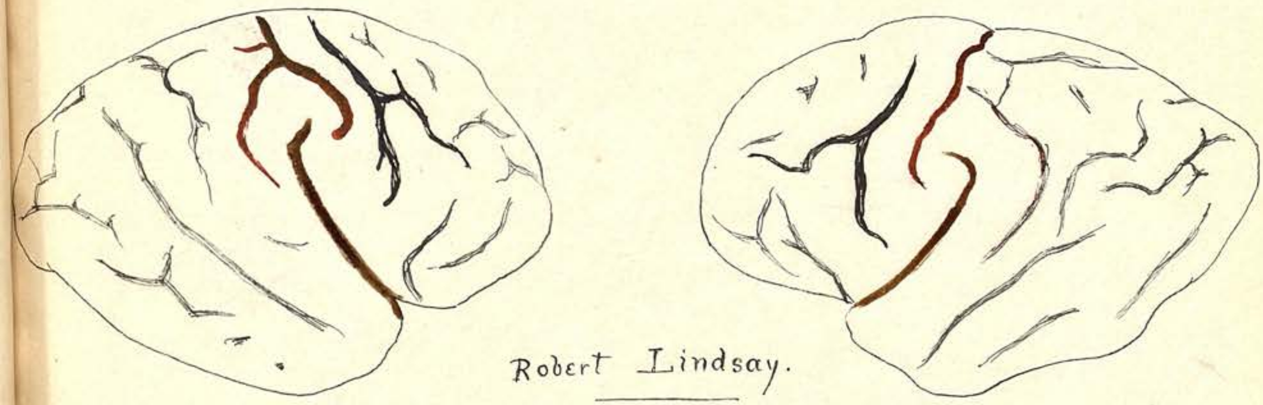
In the left hemisphere of the brain figured by Mingazzini in I900, a very instructive condition is present. The two fissures are of such a length that their ends overlap, and as a result, the parts which overlap have pressed against each other resulting in a bending backward of the upper end of the fissure of Sylvius (AB), and a forward bending of the lower end of the fissure of Sylvius (CD).



But in many cases this is not found, and, the two fissures being unable to arrange themselves in one straight line, are forced to arrange themselves in the next position of least resistance, which consists in their lying parallel to each other. This condition is well seen in the accompanying tracing from Marchand's figure of the brain of Georg Volp.



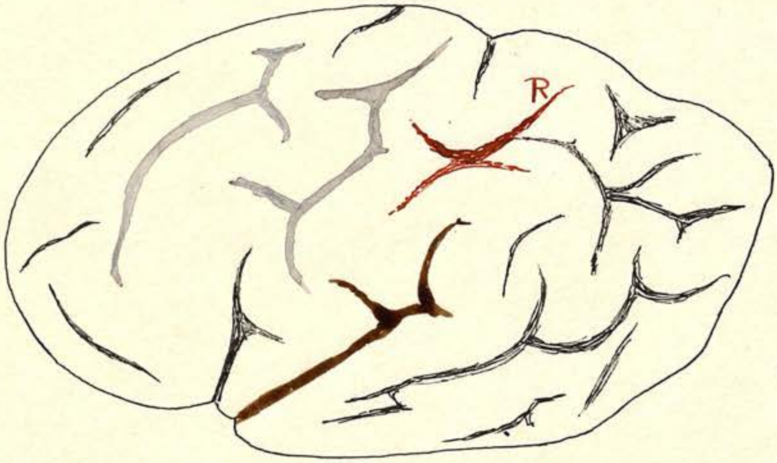
In both hemispheres of Robert Lindsay a similar arrangement is present. In the one hemisphere the fissures are almost in in one straight line, in the other they lie parallel to each other.



Robert Lindsay.

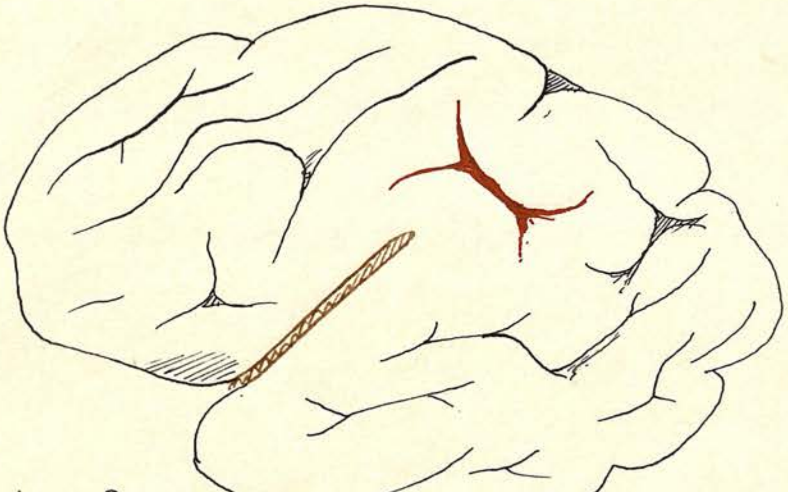
We have thus come to this conclusion;- that in the microcephalic brain there is a strong tendency for the fissure of Rolando and the fissure of Sylvius to arrange themselves in the same straight line, the result of a mechanical disturbance causing the two fissures to take up the line of least resistance. If they are unable to lie in the same straight line, then they take the next line of least resistance, i.e. they lie parallel to each other. This condition is the same as would result if a normally developing brain were suddenly arrested in its growth about the third or fourth month, and a smaller brain resembling the lower ape brain superposed upon the normal. And I have shown that this change consists chiefly in a shortening of the fissure of Rolando, with a subsequent rotation forward of the fissure of Sylvius in consequence of the mechanical disturbances in the cortex resulting from the diminished Rolandic sulcus.

But, as I have already pointed out, the fissure of Rolando in the microcephalic idiot is also characterised by a second distinctive feature, namely - the bifurcation of its lower end, and, as I have already shown, the posterior end of the fissure of Sylvius comes to lie between the two arms of the bifurcation. In order to attain this position the end of the fissure of Sylvius as it rotates forwards, slips past the lower end of the posterior arm of the bifurcation. The anterior arm of this bifurcation undoubtedly represents the fissure of Rolando. The nature and meaning of the posterior arm is more complex; Cunningham considers it represents the inferior transverse furrow, but it really represents a far more interesting condition since it is the inferior postcentral sulcus, which has undergone a very extraordinary displacement which I shall afterwards discuss in full. Its exact nature at this stage is immaterial. When the fissure of Rolando rotates forwards, it usually slips past this furrow and lies between it and the anterior arm of the bifur--cation. But, in some cases, owing either to the greater length of the fissure of Sylvius, or of the posterior arm of the bifur--cation, (usually the former) it is unable to slip past below and accordingly pushes the whole of the fissure of Rolando along with the terminal bifurcation before it, so that ultimately the Rolandic fissure becomes rotated round to form very nearly a right angle with its normal position. This condition is seen in the following figure, which is from the right hemisphere of 'Joe'. I have marked the fissure of Rolando in red, and its greatly altered position will be at once evident. This brain is also one in which I am inclined to think that the praecentral fissure has been mistaken for the fissure of Rolando, but it will be seen that the praecentral sulcus is the large Y shaped sulcus which I have coloured in blue, while the red fissure is small and ends in a terminal bifurcation and is undoubtedly the Rolandic fissure which has been displaced in this peculiar manner owing to the fissure of Sylvius being so long that it was unable to pass this posterior limb of the bifurcation and in consequence it has pushed the fissure of Rolando in front of it until it has come to occupy the position here seen.



We may also regard this matter from another point of view, since the fact that the fissure of Rolando has been so displaced and assumed such a position in relation to the fissure of Sylvius may be regarded as a proof that the fissure of Sylvius undergoes a rotation forward such as I have described.

In a paper by Dr. Heinrich Vogt (Arbeit. a. d. Hirnanat. Inst. in Zürich II, 1905) on the microcephalic brain he figures a condition which is very similar to that found on the right hemisphere of 'Joe'. He has also mistaken the praecentral sulcus for the fissure of Rolando, while the true fissure of Rolando, which I have marked in red, occupies a position very similar to that found in 'Joe'. The fissure of Sylvius here also, has been unable to sweep past the lower end of the posterior arm of the fissure of Rolando, and again has caused a similar displacement of the whole Rolandic fissure. The close resemblance between these last two brains is, therefore, of very great interest. They are the only two examples of this condition which I have been able to discover.



Tracing from Brain of C. Gravelli (p. 243).

To sum up shortly the changes which I have just described in detail, I have pointed out that the fissure of Rolando has undergone some very great change in its development which has resulted in a permanent fissure being formed which very closely resembles that found in the lower apes. As a result of this change the cortex in its vicinity has been greatly reduced, producing a mechanical interference with the rest of the hemisphere, which has manifested itself by a movement of the posterior end of the fissure of Sylvius towards this portion of the cortex where the diminution has occured this being the position of least resistance. If pssible, the two fissures arrange themselves in the same straight line; if not, they lie parallel to one another; and under certain rare conditions the fissure of Sylvius causes complete displacement of the fissure of Rolando as I have described. This condition is not to be directly compared to the human adult brain, or to the foetal brain at any period of its development, or to any ape brain, but is the condition which would necessarily result if some simpler form of brain (resembling those found in the lower apes) were to be superposed upon a normally developing three or four months foetal brain.

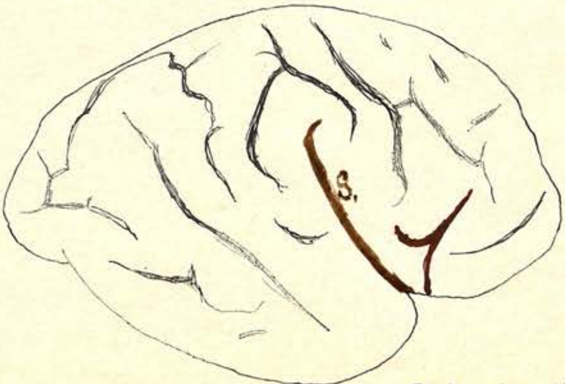
The Fronto-orbital Sulcus.

I do not propose to discuss this sulcus at any great length, since although thirteen years have elapsed since Professor Cunningham's memoir on the microcephalic idiot brain was written, the description which he has given of this furrow is so complete and concise that very little has been added to our knowledge since then. It is a constant feature in all microcephalic brains; it is almost never found in the human adult brain or at any period in the human foetus, and is present in its most typical form in the ape brain. Its presence in the microcephalic idiot brain is a most characteristic simian feature, as has been pointed out so fully by Professor Cunningham, and is a most important feature of the microcephalic brain since it is a constant furrow. To quote Cunningham's words, (p.305) :- "the Sylvian defect is one of the most striking and at the same time one of the most common features in an extreme case of typical microcephalic brain".

At this period it is convenient to study the relation of the opercula of the Sylvian fissure, and I shall again quote Cunningham (p.304) in referring to the brain of Fred :- "the frontal and orbital opercula are absent. Further, the submerged part of the insula is covered almost solely by the temporal operculum. The fronto-parietal operculum can hardly be said to overlap the insula at all. It merely forms a high perpendicular wall, which bounds the submerged part of the island above, and to which the edge of the temporal operculum is applied. It thus presents an early foetal condition".

In regard to the brain of Joe :- "The fronto-parietal boundary is in the form of a high wall, from which no over-lapping process proceeds". In the brain of Robert Lindsay the fronto-parietal operculum is exceedingly poorly developed and scarcely overlaps the island of Reil. And also in all these six hemispheres the temporal operculum is ~~immensely~~ well developed.

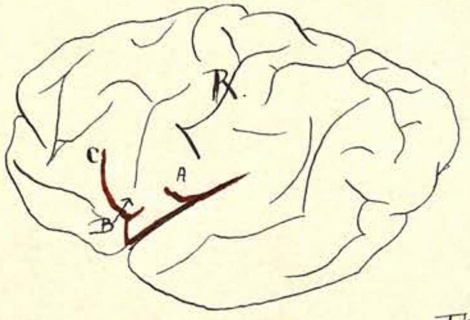
In a paper in the Journ. of Anat. and Physiol., 1904, p.158, "On an Exceptional Human Brain presenting a Pithecoid Abnormality of the Sylvian Region", Elliot Smith discusses the fronto-orbital sulcus and its relation to the various opercula. He states that the fronto-orbital sulcus represents the ramus horizontalis of the adult human brain. The ramus ascendens is secondarily formed by the bending downward of the anterior part of the dorsal operculum : this produces a kink in front of Eberstaller's diagonal sulcus, and this kink is the "ramus ascendens". "All my evidence points to the conclusion that in the vast majority of cases the frontal operculum is merely the anterior, flexed part of the dorsal operculum, and that in most cases where there is no such frontal operculum, the single ramus which is present is the representative of the ramus horizontalis of most other brains". To put this shortly, the "ramus ascendens" (i.e., "the frontal operculum" of Cunningham) is formed by the bending downward of the anterior part of the dorsal operculum (i.e., "by the growth downwards of the bounding wall in front of the fronto-parietal operculum" of Cunningham). Cunningham considers the frontal operculum is formed in front of the fronto-parietal operculum, Elliot Smith thinks it is due to an increased growth of the anterior end of the fronto-parietal operculum. The condition found in the microcephalic brain is quite opposed to the view of Elliot Smith and is in complete harmony with that of Cunningham. It is true that here we have the proof that the sulcus fronto-orbitalis represents the ramus horizontalis of the adult brain, since in these cases where the frontal operculum is slightly developed (e.g., Robert Lindsay, left hemisphere of Joe, etc.) it is present on the posterior side of this furrow (see fig. of left hemisphere of Joe), but this point is not new. It was clearly pointed out by Professor Cunningham in 1895, and therefore Elliot Smith has just restated the fact in other words, referring to "development of fissures" where Cunningham has used "development of opercula". If we examine this left hemisphere of Joe, or either hemisphere of Robert Lindsay, it will be seen that there is an incipient frontal operculum which can only be looked upon as a separate growth apart from the fronto-parietal operculum, which is absent.



Robert Lindsay.

This is brought out still rather more strikingly in the left hemisphere of "Fred", where there is a supra-Sylvian sulcus present at A., and at the point B. there is an incipient frontal operculum, which is obviously an independent growth apart from the fronto-parietal operculum. If we were to accept Elliot Smith's view as expressed in this paper, then both A. and B.C. represent rami horizontales, i.e., we have two rami horizontales separated by a frontal operculum ; but as the ramus horizontalis is the name given to the fissure which is present on the anterior or inferior side of the frontal operculum, we can only conclude that Elliot Smith's view is not suitable for the microcephalic brain, while Cunningham's view affords a complete explanation of the condition here present.

In all the microcephalic brains which I have been enabled to examine, the fronto-orbital sulcus is present, and must be looked upon as a simian character, since it is not found at any period in the developing human brain.



FRED.

Frontal Lobe

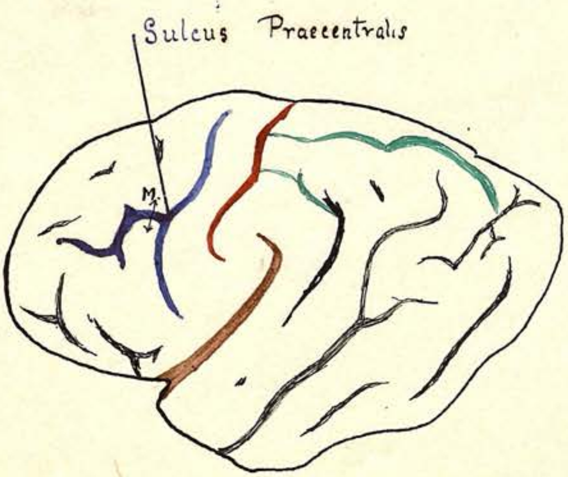
It has already been pointed out by Cunningham (p.299) that the frontal lobe is large in the microcephalic brain. This, he states "is to some extent a foetal character, seeing that in the seventh-month foetus, the frontal index is 56.7, as compared with 53.3 in the adult. Of course it is the lack of substance in the hinder part of the microcephalic hemisphere which gives the frontal lobe this spurious preponderance".

From the account which I have given of the alterations in position of the fissure of Rolando, it is apparent that I cannot compare the size of the frontal lobes in various brains by any measurement starting from the upper end of the fissure of Rolando, since this is so variable in position, and also all previous measurements must be most carefully investigated, since in many cases, the upper end of the praecentral sulcus has been mistaken for the fissure of Rolando. I propose at present to leave all such measurements alone; later, when I have described the changes which have occurred in the occipital, parietal and temporal lobes, I shall return to this subject, being then in a position to realise the true significance of the changes which have occurred and to understand fully the meaning of the relative proportions of the different areas of the brain as regards actual or apparent increase or decrease in size. I shall at this stage limit myself to a study of the fissures alone, excluding the sulcus fronto-orbitalis, as this has already been discussed.

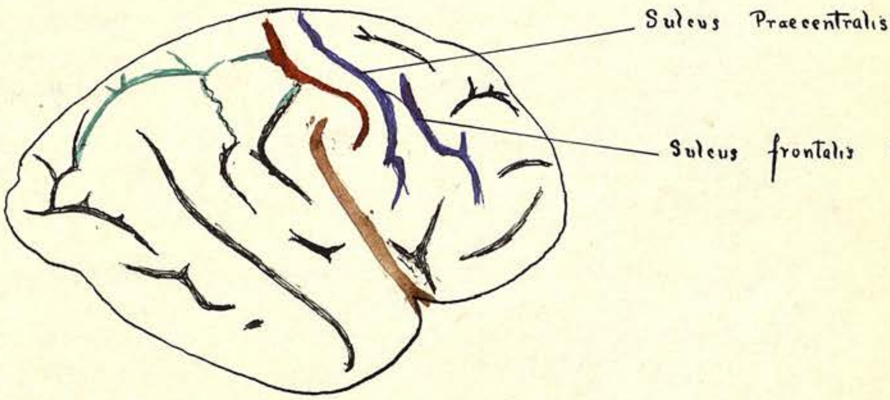
The frontal lobe is very poorly supplied with fissures, considering the large area which it usually occupies. The fissures which are typically found are four in number :

1. Sulcus praecentralis superior ;
2. " " inferior ;
3. Sulcus frontalis superior
4. " " inferior.

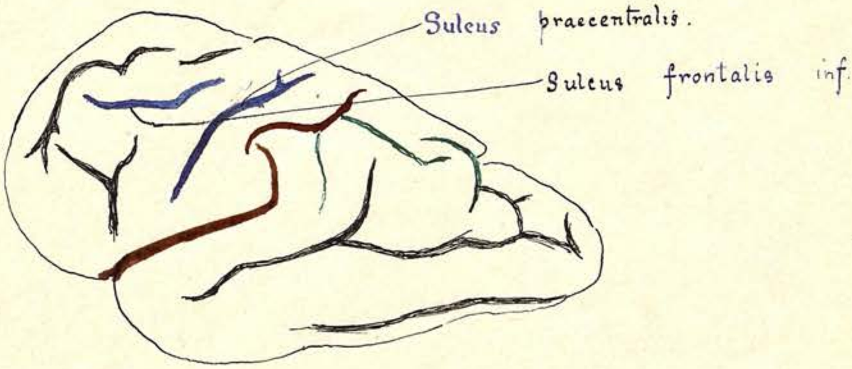
The frontal lobe is characterised principally by the well-marked and deep fissure which is situated in front of the fissure of Rolando, and which has been so often mistaken for it. The most usual appearance for this furrow to assume is that of a Y, and this is seen very well in the left hemisphere of Robert Lindsay. Here there is no difficulty in distinguishing this furrow from the fissure of Rolando. This furrow probably consists of three united furrows, the inferior praecentral, the superior praecentral and the inferior frontal.



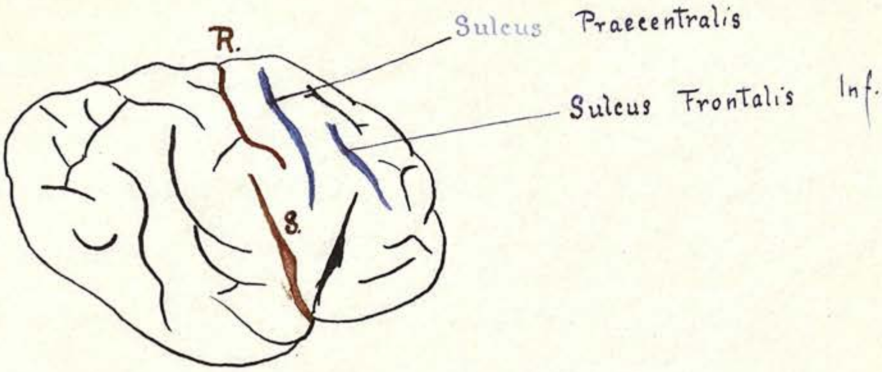
In the right hemisphere of Robert Lindsay, this furrow is broken up into two parts, so that the part which may be looked upon as the inferior frontal sulcus is found separated from the ascending inferior praecentral sulcus. If we open up the left hemisphere of Robert Lindsay at the junction of the two arms of the Y, it will be seen that the inferior frontal arm is separated from the ascending piece by a deep but well-marked buttress, (M).



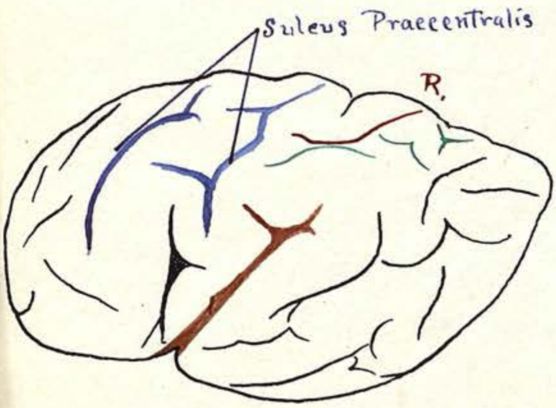
In the left hemisphere of the brain of Helene Becker, described by Bischoff, a similar condition is found, the frontal sulcus being separated from the praecentral sulcus.

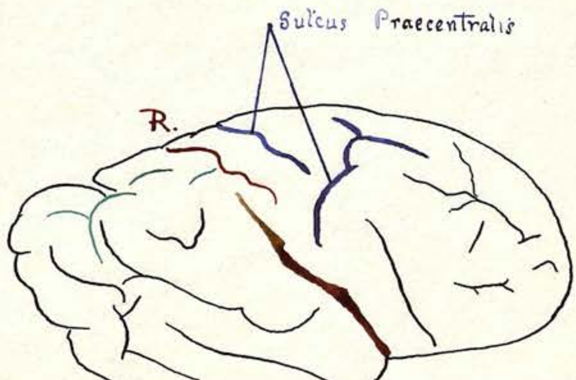


In the right hemisphere of Fred, the same condition is present as in the right hemispheres of Robert Lindsay, with this addition, that there is a submerged buttress at the upper end of the ascending praecentral fissure.



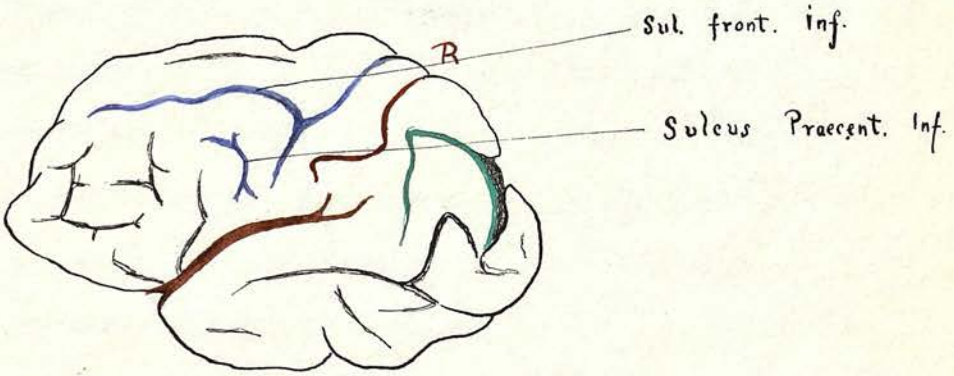
In the right hemisphere of Joe, the inferior frontal sulcus is separated from the praecentral sulcus completely, But, it will be noticed that the two together form a Y, which is the typical form of the praecentral sulcus in the microcephalic brain. And if this be compared with the left hemisphere, I think there can be no doubt that the two large fissures which I have marked in blue, represent the typical Y shaped praecentral sulcus. In fact, this shape of the praecentral sulcus is to be looked upon as a guide to the correct recognition of it, and to distinguish it from the fissure of Rolando.



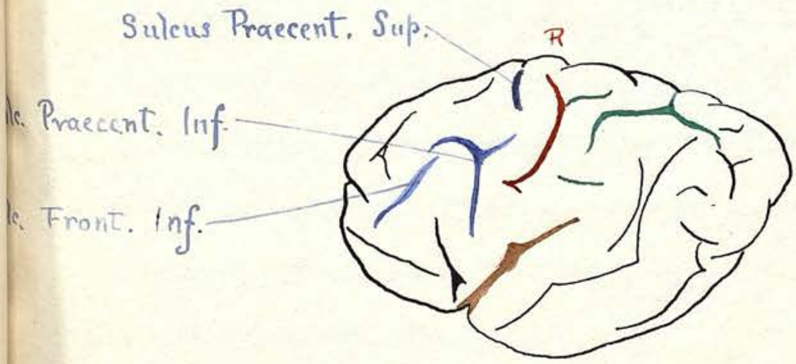


other similar examples will be seen in the brains of Perona Mauro and Rubiolio Modesta, as figured by Giacomini in I890.

In the following brain described by Mingazzini in I900, an unusual condition is found, since the inferior frontal sulcus is united with the superior praecentral, and though this latter is prolonged downwards to a slight extent, the true inferior praecentral sulcus appears to be the fissure which lies below and just anterior to it, and which is well-marked, deep and prominent.



In the left hemisphere of the brain of Fred, however, a most instructive condition is to be found. All the three components of this Y shaped fissure are separate from one another; and this is all the more interesting because in this brain, the ape type predominates over the foetal type.



I think I have now brought forward sufficient evidence to demonstrate that A large, deep, well-developed and prominent praecentral sulcus is a very constant feature of the frontal lobe of the microcephalic brain. It is typically found in the shape of a large Y. In most cases the two arms of the Y are united together; occassionally the inferior frontal sulcus may be separate from the inferior praecentral; still more rarely the superior praecentral sulcus is separate. This Y shaped fissure is very large and extends over a great part of the surface of the frontal lobe. It commences close to the mesial margin and extends downwards close to the fissure of Rolando, but does not as a rule pass into the fissure of Sylvius. The frontal lobe may pass forwards nearly to the anterior margin of the brain. The praecentral sulcus has been very frequently mistaken for the fissure of Rolando; this mistake is very natural because it is so well developed and the fissure of Rolando is so poorly marked and often is displaced backwards, so that the praecentral sulcus comes to occupy the position of the fissure of Rolando, and thus has been mistaken for it very frequently. The correct recognition of these two fissures is much easier to grasp if the typical forms of each is completely grasped. The praecentral sulcus is in all true microcephalic brains unusually well marked, and assumes this peculiar shape resembling the letter Y; while the fissure of Rolando is small, poorly marked and usually displaced backwards. If, therefore, we find a large well marked furrow cutting deeply into the frontal lobe, either in the form of a complete Y, or with one arm separate, we are justified in considering that it represents the praecentral sulcus and not the fissure of Rolando; and the fissure which is situated behind the stem and posterior arm of the Y will be found to represent the fissure of Rolando. And the proof that this is so will be found in its relation to the fissure of Sylvius as I have already described. If these points are clearly understood the interpretion of the fissures in such brains as that of 'Joe' becomes greatly simplified. It is very interesting to examine the fissures in the last microcephalic brain described by Mingazzini; here the sulci are very complicated and much displaced, rendering their correct recognition very difficult and yet in spite of this, mingazzini has named all the fissures correctly, or, at least, in complete agreement with the above points which I have just laid down.

There is still another fissure present upon the frontal lobe of the microcephalic brain which I have not yet described, and that is the sulcus frontalis superior. This sulcus is present almost invariably on all microcephalic brains; but it is never found as a single, long, continuous fissure as is characteristic of man. It is most frequently found as three separate sulci all situated in the same straight line, and, of these, the most posterior is usually the longest and deepest. Occasionally only two of these sulci are found, and still more rarely only one. The two most anterior, when present, usually lie parallel to the mesial border of the hemisphere, so also does the third as a rule, but occasionally it is situated at right angles to this. It then comes to lie parallel to the sulcus praecentralis inferior, for which it is, at first sight, apt to be mistaken. This condition is seen in the left hemisphere of Robert Lindsay.

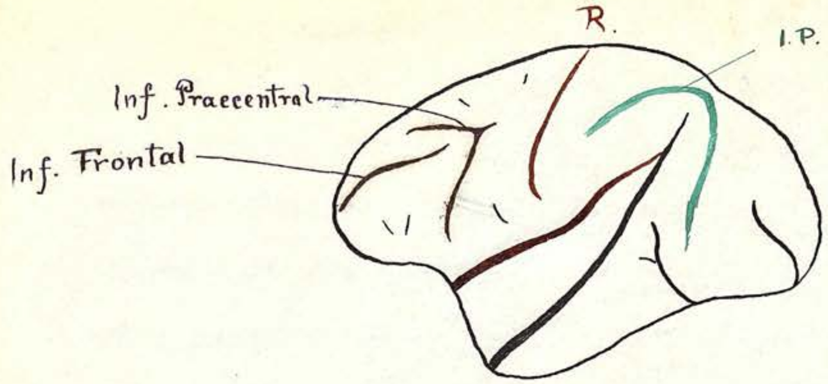
The condition of the frontal lobe of a typical microcephalic brain may be said to be as follows;-

I. (There is a well-marked sulcus fronto-orbitalis, with absence of, or incipient, orbital and frontal opercula).

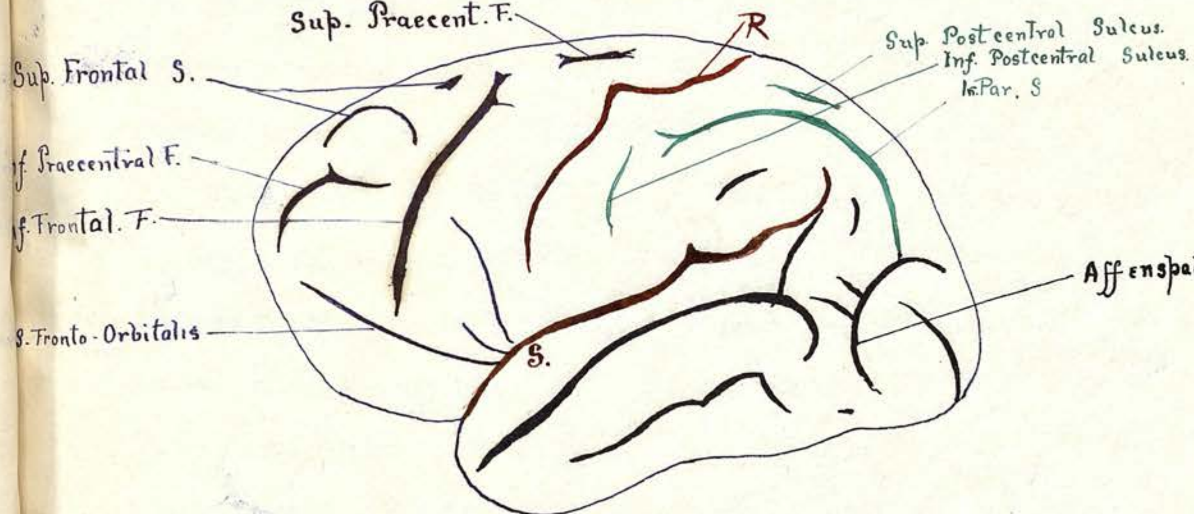
2. There is a large, deep, prominent Y shaped fissure, which consists of a united sulcus praecentralis superior and inferior, together with a sulcus frontalis inferior, either united or separate.

3. There is a sulcus frontalis superior present, either as one, two or three short furrows.

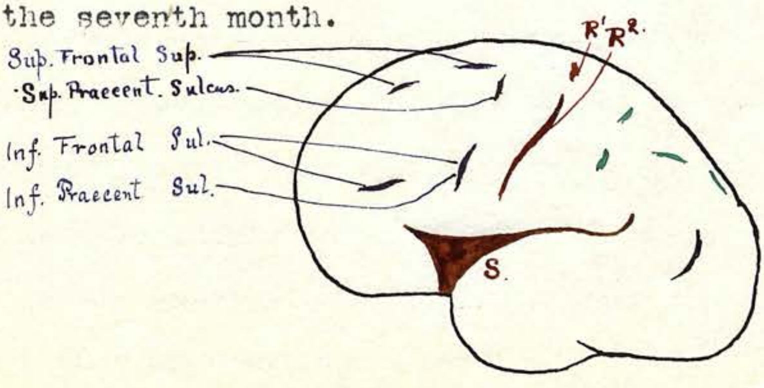
When we come to discuss the meaning and significance of the above arrangement of fissures on the frontal lobe, there are several points which are at once forced upon the attention. We have here side by side a rather curious condition, In the Y shaped fissure we have a fully developed well-marked fissure, while in the sulcus frontalis superior we have an appearance very closely resembling the human foetus. On examing the brain of one of the lower apes, e. g. Cebus or Macacus, it will be found that there are only two well marked fissures present on the frontal lobe, namely the inferior frontal and the inferior praecentral. This is shown in the following figure of the brain of a Macacus from Quain's Anatomy, fig. 280.



In the following figure from the brain of an orang, (Quain) it will be seen that there is a very well-marked inferior praecentral sulcus, and a prominent inferior frontal sulcus, and there are also present a sulcus praecentralis superior and a sulcus frontalis superior in two parts.



If we now examine the development of this area, a very interesting condition is found. The following drawing is from Cunningham. Fig. 18., Plate II. and is at the early part of the seventh month.



In the lower ape brains there are only two well-marked fissures present, the praecentral fissure and the inferior frontal fissure. In the microcephalic brain, I have just shown that the frontal lobe is characterised by the presence of a large Y-shaped sulcus. The sulcus is almost invariably present, and consists of the praecentral sulcus and the inferior frontal sulcus. Accordingly, the first fact which comes to our notice is that the fissures which are present on the frontal lobe of the microcephalic brain, are the same as those which are present on the low ape brain. But there are in addition, on the low ape brain, a number of extra fissures; These consist of the superior frontal sulcus in one, two or three parts, i.e. it represents a foetal condition. So that in this brain we have side by side purely foetal characteristics along with marked simian resemblances. The explanation of these facts is very complete, if we regard it from the point of view of the superposition of the simian type of brain upon a foetal. Here the condition is such that there is no great mechanical disturbance as the result of this change. The brain has apparantly developed normally for a certain length along the lines indicated by the above diagram of a foetal brain, but when the growth disturbance occurred, only certain of these fissures were required by the superposed brain, and accordingly in the subsequent development of the brain only those will be formed, while the remaining fissures will remain in the foetal condition. This is exactly what has occurred here. When the brain arrest occurred, only the praecentral and inferior frontal furrows developed further, since these are present alone in the frontal lobe of the superposed brain, while the superior frontal sulcus remains in its embryonic state, and the middle frontal sulcus, the sulcus paramedialis and others which are not in process of formation at the time this growth arrest has occurred, are entirely wanting.

The Intraparietal Region.

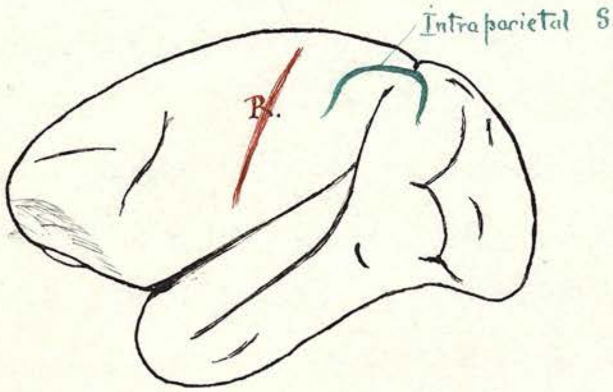
The parietal region in the microcephalic brain exhibits a diminution in size and convolutionary arrangement which is one of the most characteristic features of this condition, the full significence of which, as far as I can determine, has not yet been recognised. The essentail point to be grasped is the condition of the parietal region in the adult, foetal and ape brain. The parietal region in the microcephalic brain is not directly comparable to any of these three types; it represents a distinct type of its own. And the question which I now wish to discuss is, first;- the varieties which this type may assume; and, second;- the causes which have been at work in producing such a condition. I propose to commence this subject by a comparison of the ape parietal region with that of the human foetus and adult brain.

The intraparietal sulcus in man consists of four parts;

Sulcus postcentralis superior,
Sulcus postcentralis inferior,
Ramus horizontalis, and
Ramus occipitalis.

(I do not, at this stage, propose to discuss the nomenclature which Elliot Smith has introduced, as it does not affect the points at issue).

In the lower apes, the intraparietal sulcus is a single, short, deep and continuous furrow. This is very clearly shown in the following figure of the brain of a Capuchin Monkey (Cebus), which I have traced from p. 294 of the 1908 edition of Quain's Anatomy.



The intraparietal sulcus is, in the lower apes a short, deep single sulcus, which becomes broken up in several separate elements in the human brain.

I cannot but do better at this stage than quote from Cunningham's memoir P. (241);-

The intraparietal sulcus, single and continuous in some of the lower apes (E. g. Cebus) becomes broken up in the human brain into a group of furrows which present different relations to each other in different cases.

"Three of the elements of the sulcus in the human brain, viz. the sulcus postcentralis inferior, the ramus horizontalis, and the ramus occipitalis, are disrupted portions of the original fissure; one, the postcentralis superior, is a superadded element."

" In the development of the sulcus in the human foetal brain all the four segments of the sulcus have as a rule an independent origin, although as Pansch has shown the sulcus postcentralis inferior and the sulcus horizontalis very frequently appear as one continuous furrow".

"The sulcus postcentralis inferior usually appears first; then the ramus horizontalis and ramus occipitalis; and last of all the sulcus postcentralis superior."

"In Cebus there is no sulcus postcentralis superior; it is present, however, in most of the old world apes, e.g. the baboon, macaque, gibbon, chimpanzee, orang, and gorilla."

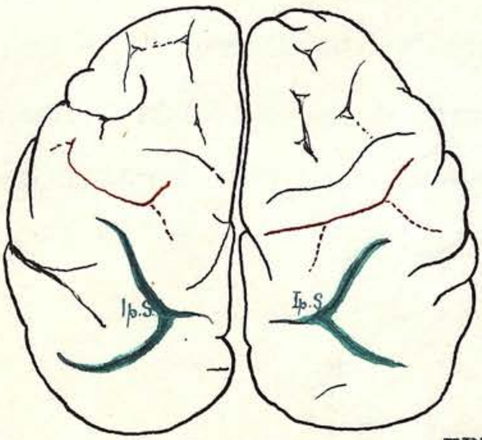
"In the apes the intraparietal sulcus is deeper than the fissure of Rolando; the opposite is the case in man. This would seem to indicate that the morphological value of these sulci is different in man and the apes. The phylogeny and ontogeny of these furrows are in apparent variance with each other. The fissure of Rolando appears first on the developing cerebrum of the human foetus, yet it is the intraparietal sulcus which first makes its appearance in the evolution of the primate cerebrum."

The intraparietal sulcus in man and the apes may thus be summarised as follows;- In the lower apes the sulcus takes the form of a single, deep continuous furrow, which in the more highly complex human brain, becomes broken up into three separate elements (to which a fourth is added later) and these three elements, in the foetal brain, are found to arise independently of each other, i.e. have a separate origin.

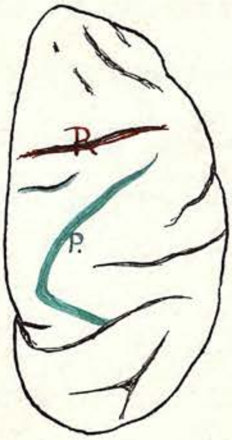
If we now apply the view which I have emphasised so strongly in connection which the microcephalic brain that the condition is the result of the superposition of an ape-like

brain upon an already partially developed normal foetal brain. it will be at once apparent that the structural changes which will result will be very considerable, and will not bear a direct resemblance to either the ape or the foetal brain; and as is at once apparent from a study of foetal brains the time of appearance of the different furrows is subject to considerable variation, the resulting condition will show a corresponding degree of variation in the ultimate structural condition.
I now propose to trace the condition and variations in this region in those microcephalic brains in which the record is sufficiently complete and exact to make any results based upon a subsequent examination reliable.

As the two hemispheres of Fred exhibit a very typical condition of the intraparietal sulcus, I cannot but do better than start with a description of the condition present here. Cunningham (p. 320) describes it as follows;- "in many microcephalic brains we may remark a tendency to the simplification of the intra--parietal sulcus, or, in other words, to a reversion to its original ape-like form. The two hemispheres of Fred afford an excellent example of this. The intraparietal sulcus is a single oblique furrow, which extends diagonally across the parietal lobe. Reaching the arcus parieto-occipitalis it sends a branch upwards in front of this convolution, and then bends downwards to join the "Affenspalte". Here there is almost an exact reproduction of what is seen in many of the lower apes. This single sulcus represents the sulcus postcentralis inferior, the ramus horizontalis and the ramus occipitalis of the normal human brain, and on the left side the furrow is uninterrupted throughout its whole length. ..... The sulcus postcentralis superior, which is to be regarded as a more or less independent element which has become linked on to the intraparietal furrow system in the human and higher ape brains, is entirely absent in both hemispheres of Fred." I reproduce here the brain which he has compared it to, as well as the brain of Fred, and it will be at once apparent how very close the resemblance really is.

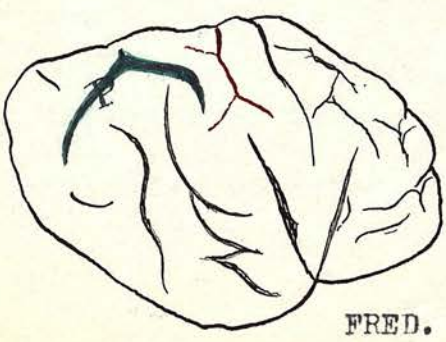


FRED.

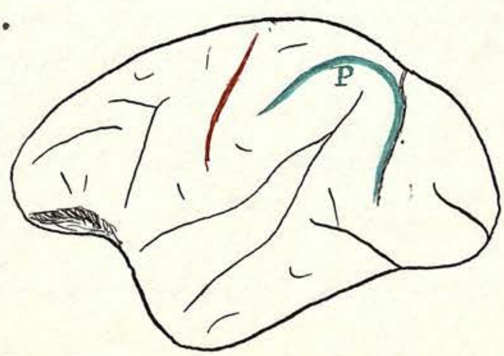


SEMNOPITHECUS. (?).

The appearance of this parietal region from the side also is very characteristic, and brings out the resemblance between the intraparietal sulcus in the microcephalic brain and in the ape in an even more striking manner.

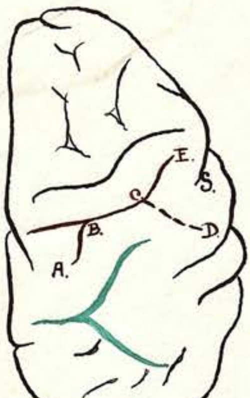


FRED.



MACACUS. (Quain 1908, p. 295).

The intraparietal sulcus in the microcephalic brain is a single fissure, usually deeply marked, and forms a curved or V-shaped furrow round the upper ends of the first and second temporal fissures. According to Cunningham (p. 321) this "single sulcus represents the sulcus postcentralis inferior the ramus horizontalis and the ramus occipitalis of the normal human brain. But, there is one point which is at once apparent from these drawings, namely;- that there are two fissures passing outwards from the fissure of Rolando, the full significenc of which, has not yet been recognised. These two fissures I have marked respectively AB and CD. There can be no doubt that the part I have marked CE represents the lower end of the fissure of Rolando, which has been pushed forwards by the rotation upwards of the fissure of Sylvius.



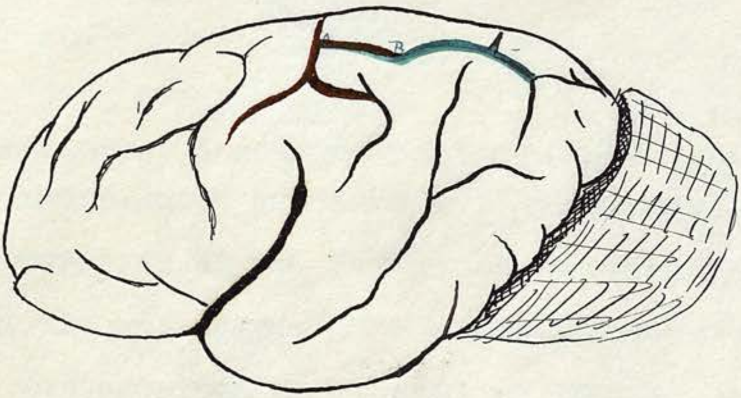
FRED.

Therefore, there are two points to which I specially wish to draw attention to in this brain;-

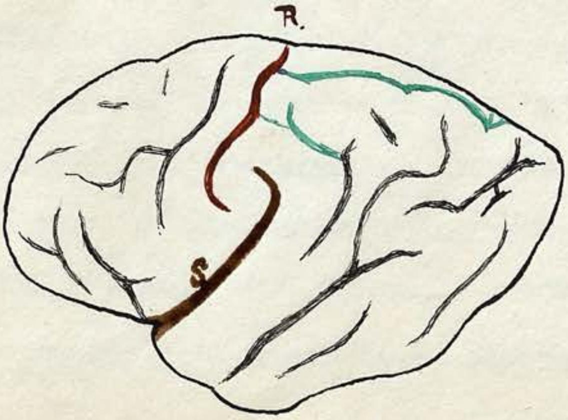
First; the intraparietal sulcus is quite distinct and separate from the fissure of Rolando;

Second;- the fissure of Rolando shows two fissures passing out from it towards the parietal region, (one of which I have already described as the "terminal bifurcation".

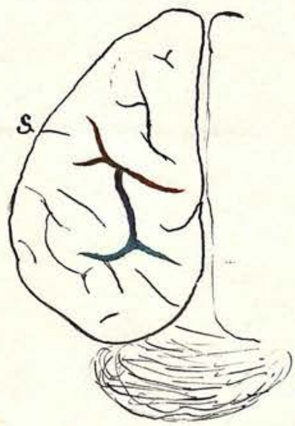
If we now examine the brain of the microcephalic idiot, described by Macnamara and Burne in the Jour. of Anat. 1903, p. 260, we find a condition very similar to that in the brain of Fred, except that the intraparietal sulcus is united with the upper of the two fissures which passes from the fissure of Rolando posteriorly. (AB)



In the left hemisphere of Robert Lindsay, a similar condition is found, the intraparietal sulcus passing into the fissure of Rolando.

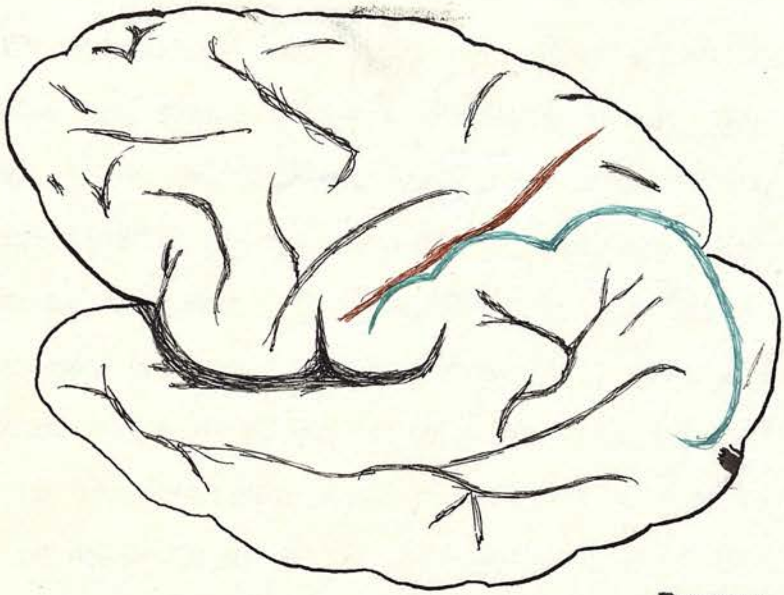


In the left hemisphere of the brain described by Marshall and Gore, the same appearance is again found, the intraparietal sulcus passing into the fissure of Rolando.



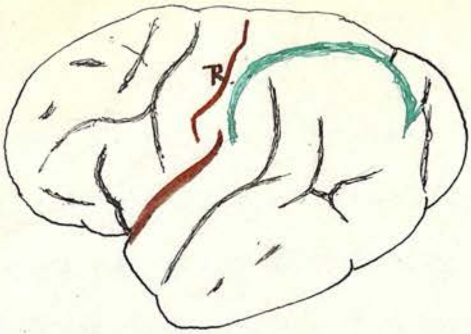
At this stage it is necessary for me to draw attention again to the confusion which has existed in connection with the correct recognition of the fissure of Rolando. As I have already pointed out the well marked praecentral fissure has been repeatedly mistaken for the fissure of Rolando, and in such cases the true fissure of Rolando has been named the postcentral fissure, which is, in reality, situated behind this.

In the brain described by Giacomini of Perona Mauro, a very interesting condition is found which throws considerable light upon the parietal region. The intraparietal sulcus is well_marked deep and in the shape of a semicircle; but the important point is t that the anterior part of the semicircle is continued into the fissure of Rolando, but does not actaally become continuous with it; it passes downwards very close to it but separated from it by a distinct interval, and ultimately it terminates in the posterior arm of the terminal bifurcation of the fissure of Rolando, which in this case is not prominent, since the fissure of Sylvius has come to lie posterior to this arm and has pushed it forwards, being too long to slip past underneath it.



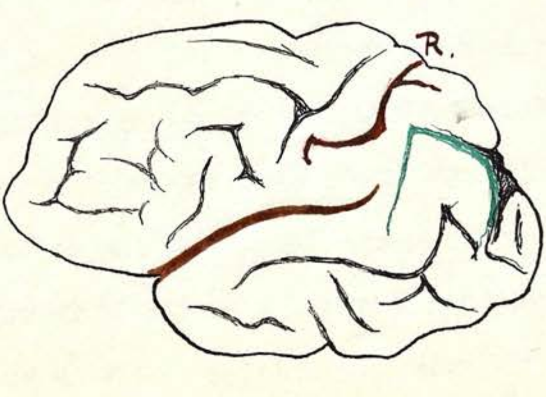
Perona Mauro.
(Giacomini).

A still more interesting condition is seen in the left hemisphere of Georg Volp, (described by Marchand) where a similar condition of the intraparietal sulcus to that described above is found, only the anterior descending part is distinct from the fissure of Rolando throughout its whole length and is separated from it by a narrow post-central gyrus, which has, obviously, disappeared from the above brain of Perona Mauro.



Georg Volp.

In the following brain we get still more light upon this question. This brain is described and figured by Mingazzini (Monat. Psych. u, Neur. Vol. 7. p. 439.) It is a brain ih which the true fissure of Rolando has been recognised, and not mistaken for the praecentral fissure which it will be noticed is well-marked and unusually far back, but still, however, retains its typical Y-shaped appearance. The intraparietal sulcus is very prominent, and is semilunar in outline, but it will be clearly seen that a long fissure extends downwards from its anterior end. This fissure and the lower end of the fissure of Rolando form the two arms of a V, and between them lies the end of the Sylvian fissure. It is evident, thus, that this furrow passing downwards from the anterior end of the intraparietal fissure is the same as I have already described as the 'posterior arm of the terminal bifurcation of the fissure of Rolando', only in this case it is separate from the fissure of Rolando.

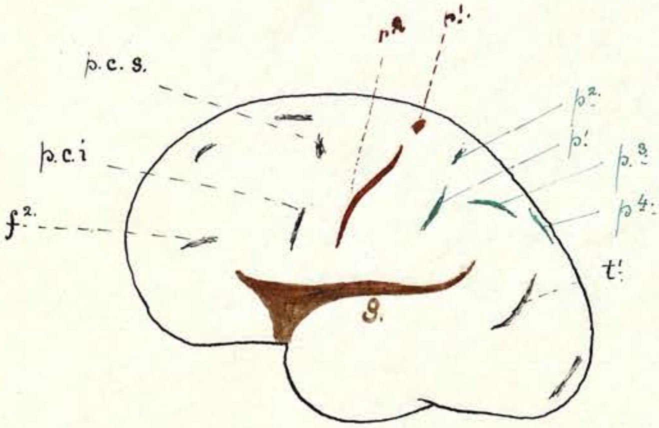


In this brain, also, it will be apparent that there is a definite ascending parietal convolution. In the brain of Georg Volp, this postcentral gyrus is very narrow; in the brain of Perona Mauro it has almost disappeared; and in the brain of Robert Lindsay it has entirely disappeared; and what has taken place is evidently this;- the sulcus postcentralis inferior has moved backwards until it has come to coincide with the fissure of Rolando, and as a result there is no ascending postcentral convolution.
The fissure which I have previously described as "the posterior arm of the terminal bifurcation of the fissure of Sylvius", which is so characteristic of the microcephalic brain is the sulcus postcentralis inferior, which has become displaced to this extraordinary degree.

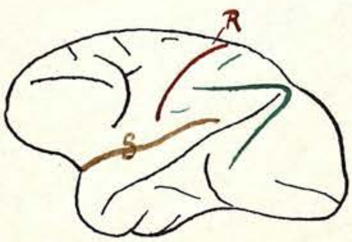
I now wish to discuss the cause which has produced such an extraordinary result; and to do so must consider the resemblances and differences in the parietal region of the ape and the human foetus.

The intraparietal sulcus, in the human foetus, arises as four separate elements, of which the first to appear is the sulcus postcentralis inferior, which usually is seen about the beginning of the sixth month. "At the end of the sixth month, or more usually at the commencement of the seventh month, the ramus horizontalis and the ramus occipitalis come into view". But these fissures are the result of the difference in the rates of growth of different parts of the cerebral cortex, and thus, although the fissures are not formed at the third or fourth month, still the growth is taking place which will ultimately lead to their formation.

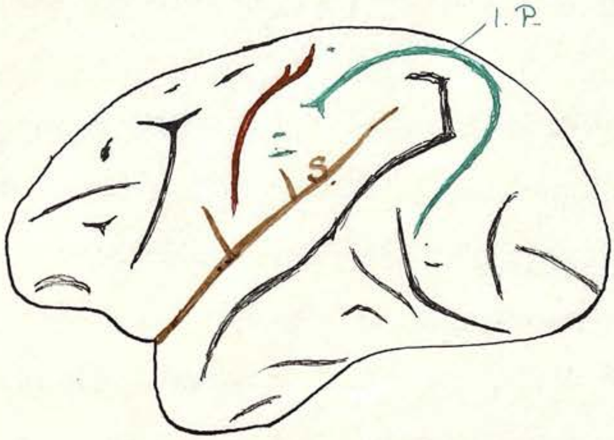
The following figure illustrates the separate development of the different elements, and is in the early part of the sixth month. (It is copied from Fig. I8, Plate II, of Cunningham's large memoir.).



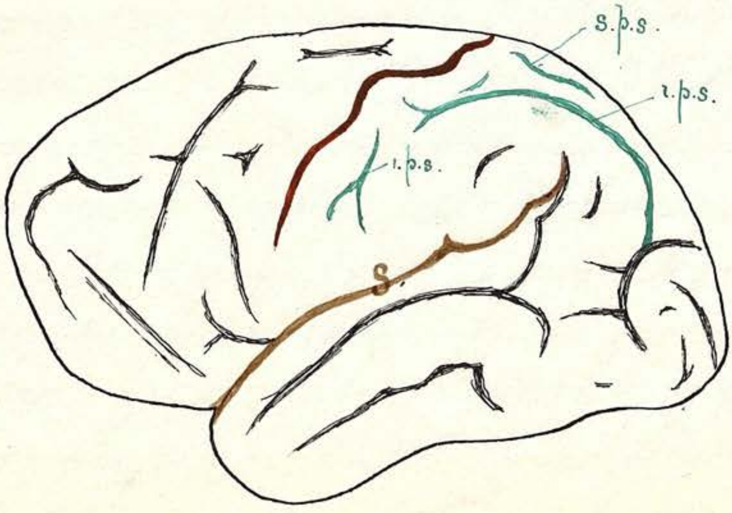
Cunningham also states (p. I97) that the intraparietal sulcus is single and continuous in the lower apes, and in the process of its evolution it has become broken up into three separate furrows in the human brain. In other words " in the process of its evolution the disruption of an originally single and con--tinuous fissure has taken place". This single and continuous fissure is well seen in the following two brains. The first is the brain of a Macacus (Fig. 242, Mus. of the Coll. of Surg. England, Vol. 2. I892);-



The second is the brain of a baboon. (Fig. 282, Quain's Anatomy, 1908);-



In both those two figures it will be seen that the character of the intraparietal fissure is well shown; it is a deep, prominent and well-marked semilunar fissure; and there is no trace of either a superior or inferior postcentral sulcus.
In the following brain of an orang (Quain's Anatomy, p. 299) it will again be seen that the intraparietal sulcus is large and prominent, and both the superior and inferior postcentral sulci are present and separate from the semilunar intraparietal sulcus.



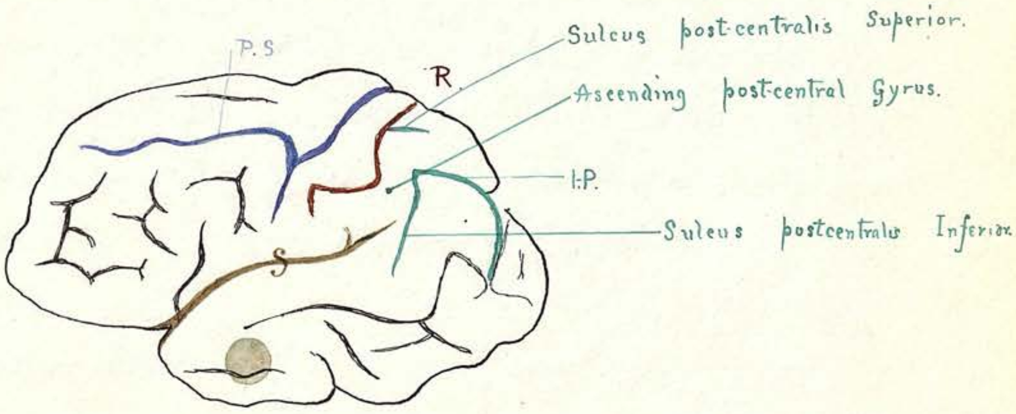
In this orang brain, we may, therefore, look upon this inferior praecentral sulcus as being the first disruption of the single intraparietal sulcus. But in the human foetus these disrupted elements develop apart from each other.

The microcephalic brain has undergone some arrest of development, presumably about the third month. Up till this time the development has been normal, and has been such that it would, in the normal course of events, have resulted in the separate development of these three elements of the intraparietal sulcus. But an alteration has occured in the development, it has not proceeded along the normal course but instead has followed the line of a simpler type of brain, a brain which has a very great resemblance to the ape brain, and as a result we find the superposition of this simpler type of brain upon a so far developed normal brain. When this alteration has taken place the parietal region will be greatly affected, the development tending to produce this large deep single intraparietal fissure. And as the parietal region is much smaller in the ape compared with man, there will be a corresponding reduction in size. At first sight, it might be expected that the natural result of this change would be to cause the three elements previously developing separately to become united to form a single and continuous furrow again, but this is not what has occurred. Only the ramus horizontalis and the ramus occipitalis have been affected in this change. The deep, single intraparietal sulcus of the microcephalic brain is the result of a union of the two above mentioned furrows only.

The inferior postcentral sulcus is situated too low down and forward to be affected directly by this change so as to bring it into union with the other two and thus reform, as it were, the single sulcus of the ape. But this altered development has affected this sulcus also, though not in the above manner. The presence of this deep intraparietal sulcus in the microcephalic brain denotes a great and rapid growth on this region, and as a result it will encroach upon the surrounding areas. But as I have already described in Robert Lindsay, and wil will discuss form fully in detail later, it cannot extend backwards owing to the changes which have occurred in the visual cortex in the occipital area, and thus it has to find room for its growth in some other region. It has extended as far upwards as possible; this is shown by the great depth of the furrow and the fact that its lower bank tends to be opercular. It is unable to extend downwards owing to the great mass of the temporal region below; and therefore it can only extend forwards. this, apparently, being the path of least resistance. In front of this region we have the fissure of Rolando, and behind it the slightly developed inferior postcentral sulcus. But this latter sulcus is very poorly developed compared to the deep intraparietal sulcus, and, in consequence it offers very little resistance to the rapidly growing parietal area, and therefore is pushed forwards until it ultimately reaches as far as the fissure of Rolando with which it coincides finally. I cannot point out any better example to demonstrate and prove this point than the left hemisphere of Georg Volp.

I have already a few pages back reproduced a tracing of this b brain, showing the intermediate condition where the inferior postcentral sulcus has not quite coincided with the fissure of Rolando, but has nearly done so. There is a small ascending postcentral gyrus, which is in process of obliteration, being sunk to some extent below the level of the surrounding surface. It may be argued that it is not very trustworthy to draw important conclusions from figures the accuracy of which one is not certain; but, fortunatly, in this case this objection may be dispended with since a very accurate model has been made of this brain by Marchand, and one of these is in the anatomical department, and from it one is able to draw conclusions which, one would perhaps not be so justified in doing from a drawing.

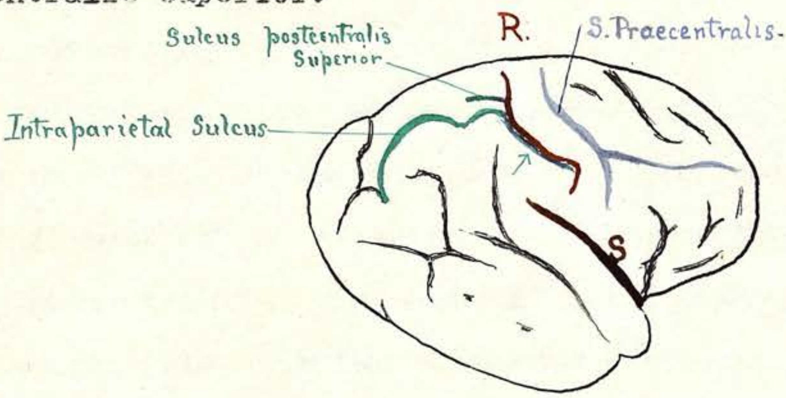
The time of medullation of the ascending parietal gyrus is not accurately known. Flechsig states that it medullates at the same time as the ascending frontal gyrus and he numbers them both together as I in his series. We know that in man and the anthropoid apes the two convolutions have different functions, and from the work of Simpson and Jolly we know that the same is the case in the lower apes, and that, whatever is the function of the ascending parietal convolution it is not motor. A. W. Campbell has shown that the histological appearance of these two areas are entirely different from each other, and has stated that the statement that the ascending parietal and ascending frontal convolutions medullate at the same time requires further investig--ation. At whatever period it does medullate it has in the microcephalic brain offered very little resistance to the rapidly expanding parietal area. In the following brain described by Mingazzini, I have shown that the ascending postcentral gyrus is



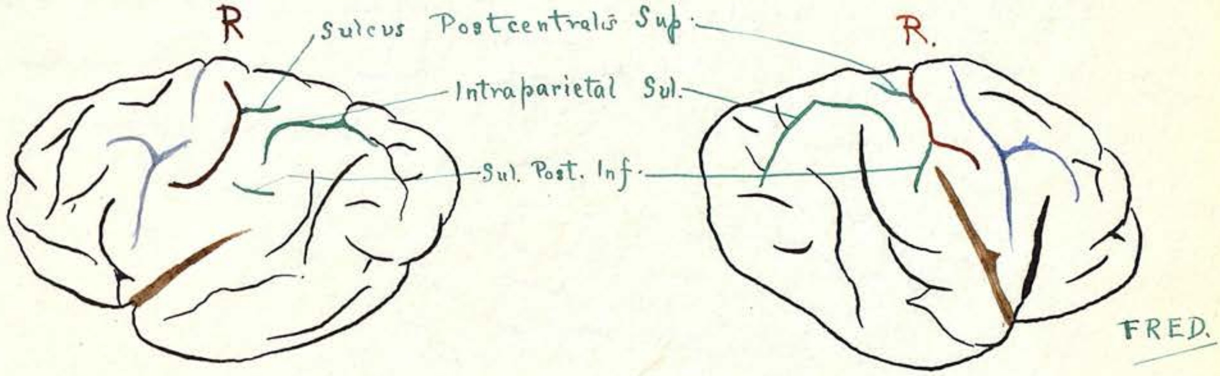
well marked and bounded posteriorly by the inferior postcentral sulcus, which probably marks the anterior limit to the parietal region in this case, i. e. to that region which appears to be so greatly altered in its rate of growth. But I also wish to draw attention to a small sulcus which passes backwards from the upper end of the fissure of Rolando. In the above diagram I have coloured it green. It is a sulcus which is entirely separate from the intraparietal sulcus, and probably represents the sulcus postcentralis superior. That it passes directly into the fissure of Rolando is clear, and this is not a condition which is found in either the human foetus, or the ape. It is typical of the microcephalic brain only. In producing this, there have probably been two conditions at work; first - the change which has affected the upper end of the fissure of Rolando resulting in the disappearance of the second and upper part of the two elements out of which this fissure is formed, has resulted in a diminution in the cortex in this area, causing an in-drawing of the surrounding cortex and with it the lower end of the superior postcentral sulcus; and

secondly- the superior postcentral sulcus has also probably been affected by the rapidly developing parietal area, and pushed forwards in a similar manner to the inferior postcentral sulcus. From the above brain it will be evident that it is the first of these two conditions which has been at work and influenced this forward movement of the superior postcentral sulcus to the greatest degree.

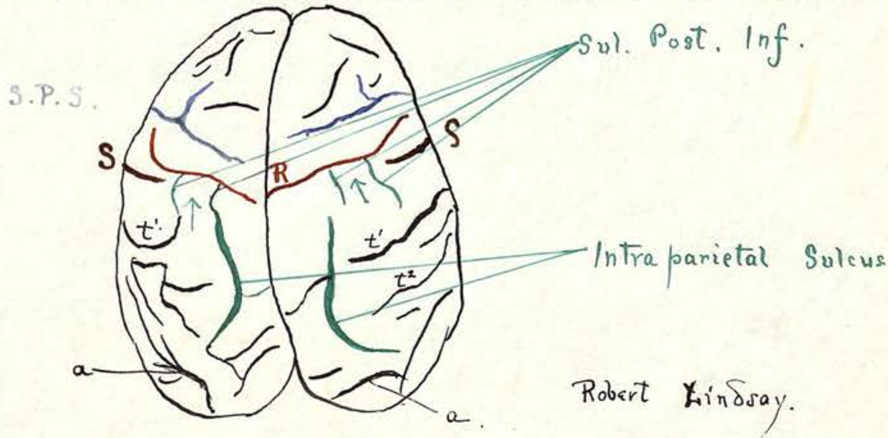
The superior postcentral sulcus is not found in all microcephalic brains. It is absent in the brain of Robert Lindsay and also of Joe. It is present in the right hemisphere of the brain of Georg Volp, where it passes into the fissure of Rolando, and as the intraparietal sulcus in this case is united to the sulcus postcentralis inferior, which has moved forwards until it has come to coincide with the fissure of Rolando, there is thus no difficulty in recognising this upper fissure as the sulcus praecentralis superior.



In the brain of Fred, the condition is very difficult to determine. It will be seen from the accompanying figure that there is in both hemispheres a prominent furrow passing backwards from the upper end of the fissure of Rolando. This fissure is certainly not part of the fissure of Rolando itself. Cunningham mentions that "it terminates at each end in both hemispheres in a wide bifurcation". The lower of these fissures is the

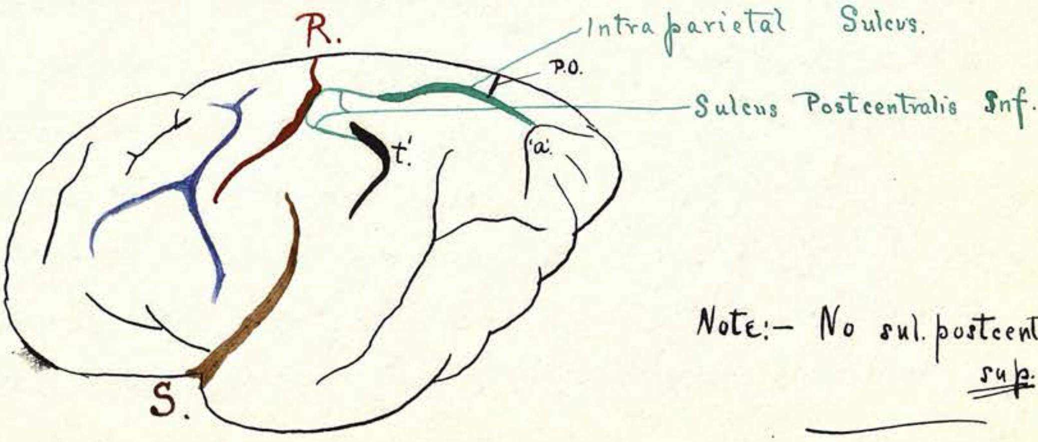


sulcus postcentralis inferior (with in some cases, to be described later, the first temporal fissure also); the upper may either be the sulcus postcentralis superior, or the upper end of the sulcus postcentralis inferior, in which case, it probably is the fissure formed by the union of the superior and inferior fissures. in both cases it thus represents the superior postcentral sulcus. In this brain we get a very good example of this disappearance of the postcentral gyrus. That this is the superior postcentral sulcus is also supported by the fact that it lies entirely to the inner side of the intraparietal sulcus, (i.e. mesial side). But it must not be considered that every fissure which passes backwards from the upper end of the fissure of Rolando is necessarily the superior postcentral sulcus. In both hemispheres of Robert Lindsay, such a sulcus is found; and also in both hemispheres this sulcus terminates in the one hand in the fissure of Rolando, and in the other in the intraparietal sulcus. And when this upper sulcus does unite with the intraparietal sulcus it is the upper end of the true inferior postcentral sulcus. The early condition has resembled that found permanently in the brain described by Mingazzini (and which I have figured four pages previously). The parietal region as it began to grow more rapidly has pushed this inferior postcentral sulcus before



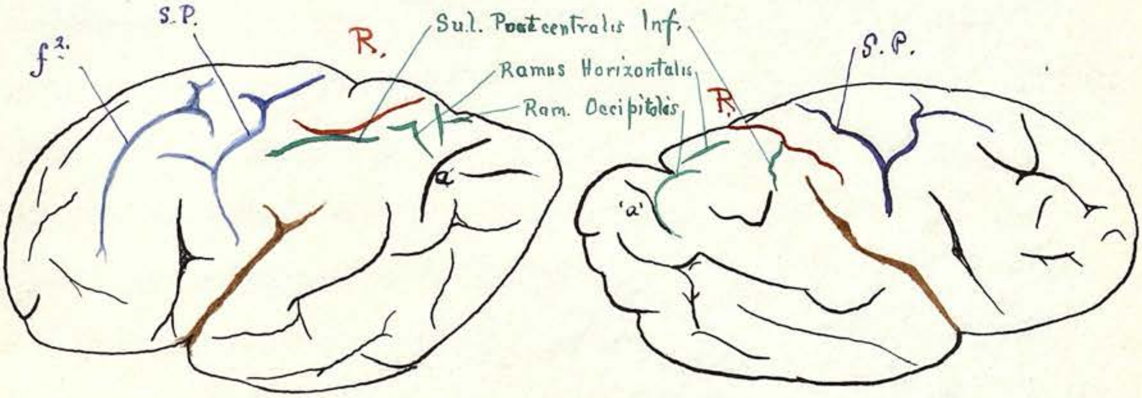
it until it has taken the form of a U, and therefore, in this case both fissures which pass backwards from the fissure of Rolando represent the upper and lower ends, respectively, of the sulcus postcentralis inferior.

An exactly similar condition of the inferior postcentral sulcus is seen in the following brain described by Macnamara and Burne in the Jour. of Physiol. 1909. (p. 260).

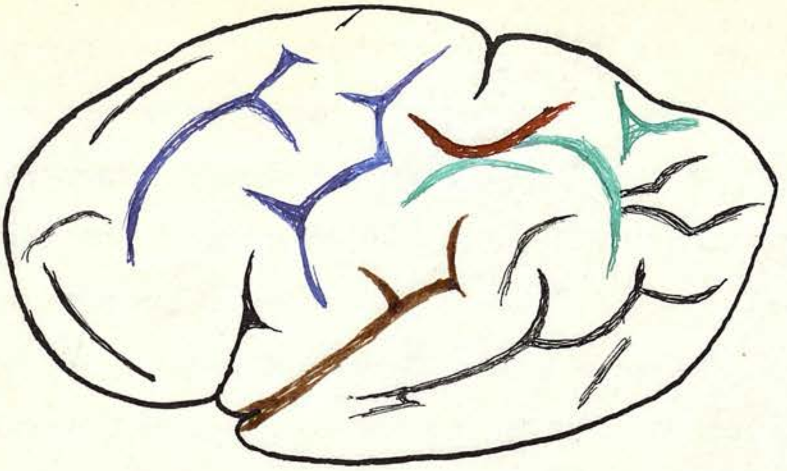


Note:- No sul. postcentralis sup.

But before I conclude this description of the parietal region in the microcephalic brain, I shall just point out several variations in the arrangement of the fissures which may occur. This variation consists mostly in the separation of the various elements, so that they do not ultimately unite to produce the ape condition of a single and continuous fissure, bur rather tend to resemble more closely the foetal condition. This is well seen the brain of Joe.



In both these above two hemispheres the intraparietal sulcus is in three separate elements, i. e. it represents the foetal condition; and this is all the more interesting since the fissures in the frontal lobe also are very deficient in number and separate from each other, so that this brain represents the foetal type far more than the ape type. But, although it is very clear from the above that the intraparietal sulcus is divided into its three separate elements, this is not so clear when the hemisphere is simply looked at superficially. The above appearance is seen when the sulcus is opened up. In the following figure I have reproduced a tracing from the brain of Joe, and in it I have tried to represent the superficial

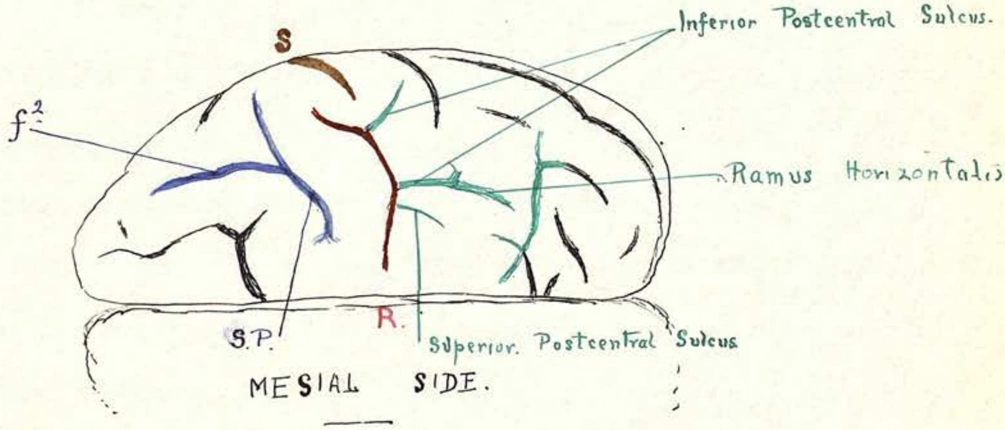


appearance of the brain, and it will be seen that there is a well marked 'parietal operculum', and that the intraparietal sulcus in this brain is represented by the 'ramus horizontalis' only. In this case the rotation backwards of the fissure of Rolando has resulted in a displacement downwards of the parietal area, and in consequence, the ramus horizontalis has been widely separated from the ramus occipitalis. When the change in the growth of the parietal area occurred, the increased rate of growth has affected the ramus horizontalis only, and this has become enlarged deep and prominent as shown in the above figure. But, apart from this rotation of the fissure of Rolando backwards, we also are dealing here with a brain which shows a great many other foetal resemblances, and therefore, we have had this alteration in the growth of the brain and subsequent superposition of a simpler and ape-like type of brain impressed upon a brain where the foetal furrows have either been formed early, or the change in the growth have occurred late. But the change which has occurred in this brain is the same as in all other typical microcephalic brains. The attempt has been made to convert the separate elements of the intraparietal sulcus into a single and continuous sulcus

In most cases, the ramus horizontalis and the ramus occipitalis are converted into a single continuous furrow, and the inferior postcentral sulcus is displaced anteriorly; occasionally, however, only the ramus horizontalis is affected, and in this case, it is it only which is enlarged, deepened and forms the mesial boundary of the parietal opercelum of the ape brain. The 'ramus occipit--alis', or 'sulcus paroccipitalis' of Elliot Smith, is a curved fissure which is formed on the surface of the brain in consequence of an indentation on the mesial surface of the parieto-occipital fossa, or, more accurately, that part of the fossa which later is known as the incisura parieto-occipitalis. In the microcephalic brain the parieto-occipital region shows a great variety of changes which I shall discuss when I come to describe the occipital region, but in the great majority of cases what has occurred in the parietal region of the microcephalic brain is that, the sudden increased rate of growth has resulted in a great increase in size, depth and length of the ramus horizontalis which has either become united with the ramus occipitalis end to end to form a strong prominent furrow, or it has coincided with it in the same way that the inferior postcentral sulcus has come to coincide with the fissure of Rolando.

In the description which I now conclude of the intraparietal sulcus and the parietal region, I have dealt principally with the anterior part of this region. The posterior part is so closely wrapt up in the changes which have occurred in the occipital region, that I propose to leave the discussion of the arrangement of the fissures and convolutions in the posterior part of the parietal lobe until I come to discuss the occipital region.

Before finishing, I should just like to draw attention to the following figure of the brain described by Bischoff, (Helene Becker). Here it will be seen that three sulci pass backwards from the fissure of Rolando. Of these I



consider the first is the superior postcentral sulcus, the lowest is the inferior postcentral sulcus, and the middle is either the posterior and upper end of the inferior post--central sulcus, or it is the anterior end of the ramus horizontalis, and there is no ascending parietal gyrus. (I shall discuss that posterior part of the parietal region in this brain shortly).

I may summarise the changes in the microcephalic parietal region as follows;-

In the superposition of the ape type upon the foetal, an attempt has been made to reform the single continuous intraparietal sulcus. But, of the three parts into which this sulcus has been disrupted, only two take part in the reformation of this deep, continuous single furrow. The third, the inferior postcentral sulcus, is displaced anteriorly until it finally comes to lie (i.e. coincide with) the fissure of Rolando.

The terminal bifurcation of the fissure of Rolando consists of two arms; the anterior is the true fissure of Rolando; the posterior is the displaced inferior postcentral sulcus.

The bifurcation at the upper end of the fissure of Rolando may consist of one of two fissures; it may either be the superior postcentral sulcus, or the upper end of the inferior postcentral sulcus. As in the brain of Helene Becker both may be present; if only one is found, if it is directly continuous with the anterior extremity of the intraparietal sulcus then it represents the inferior postcentral sulcus.

There is apparently no postcentral gyrus.

When I commenced this investigation of the characters of the brain of the microcephalic idiot, I very soon found that since Cunningham's paper on this subject no serious attempt had been made to collect all the cases of true microcephaly already published and to correlate these to each other. Almost all the conclusions which have been arrived at on this subject have been drawn from the observation of a single, or at most two specimens. This is altogether insufficient data upon which to base any wide generalisation, and it is even insufficient to allow of a correct recognition of the different fissures. I have already pointed out that the changes which have occurred in the microcephalic brain are of a very peculiar nature, and it is a question of great difficulty, when one fissure has been so displaced that it comes to occupy the place of another, to know which fissure we really have under our notice. If, however, we examine a large number of such brains, such difficulties are overcome, because it is possible in almost every case to discover a series of intermediate conditions which at once allow of a complete recognition of the truth. And by this means also we are enabled to ascertain what features are characteristic of the microcephalic brain and are always present, and what features are not of any value, being found only on one single brain and to be regarded therefore as of very little significance in the microcephalic brain. And we can also determine what variations these characteristic features can undergo, and their nature and extent. Thus by the examination of a large number of these brains, I have been able to show that the statement of Professor Cunningham is fully justified, namely, that true microcephalic brains do conform to a certain definite morphological type, that they present a natural group outside the domain of pathology, and that this type does not resemble either the human adult, foetal or the ape brain, but has a distinctive configuration of its own.

My object now is : (1) to determine the nature of this type and its chief variations; and (2) to discover the cause which has produced such a marked deviation from the normal course of development.

The first point in the microcephalic brain to which I wish to draw attention is the fissure of Rolando. It is very necessary that this fissure should be correctly recognised. There are very few writers who have not mistaken the praecentral fissure for the fissure of Rolando, and as Cunningham has pointed out, this mistake is natural since the praecentral sulcus is unusually well developed, while the fissure of Rolando is small and badly formed, and as the praecentral fissure is often displaced backwards until it comes to occupy the normal position of the fissure of Rolando, it is not altogether surprising that this mistake should have occurred so often. But there is one point to which attention should always be directed in examining these two furrows, and that is the characteristic shape of the praecentral sulcus. In all microcephalic brains this furrow is in the form of a large Y. It may happen that owing to some deep gyrus rising to the surface part of it becomes separated from the rest, but this is quite an insignificant point; the characteristic shape is there all the same. And the fissure of Rolando is to be recognised as being the first fissure found situated just behind this Y. There is also, however, another feature of this fissure which is a guide to its correct recognition, and that is its relation to the fissure of Sylvius ; namely, that it is situated in the same straight line as this latter fissure. This is a most characteristic and important point in the microcephalic brain. If these two fissures are not in the same straight line, then they lie parallel to one another, but the first is the more common of the two conditions. There is also one other point ; the posterior termination of the fissure of Rolando ends in a terminal bifurcation between the two arms of which lies the upturned posterior end of the fissure of Sylvius. There are thus two guides to the correct recognition of the fissure of Rolando : first, the fissure of Sylvius, which can always be easily recognised, and second, the Y-shaped praecentral sulcus. Having thus established the fissure of Rolando correctly, it will next be found that it consists of a more or less straight short furrow, terminating in a bifurcation at both ends. This furrow really represents three (or it may be four) sulci all united together. The true fissure of Rolando is the two anterior arms of the bifurcation ; of the posterior arms the lower represents the inferior post-central sulcus, and often also the upper part of the first temporal, the upper posterior arm being either the sulcus post-centralis superior, or, if this is absent, the upper end of the inferior postcentral sulcus. All previous writers have given the name of "Fissure of Rolando" to this combined fissure. The first point, therefore, which is to be regarded as typical of the microcephalic brain is :

(1) <u>The Fissure of Rolando</u> :

It is short and usually straight ;

It possesses smooth walls and no deep annectant gyri ;

It ends posteriorly in a terminal bifurcation ;

It may also end anteriorly in a terminal bifurcation.

The fissure of Rolando itself shows this curious ape-like character, the most important point of which is the absence of deep gyri or buttresses, showing that it has developed in one, and not in two parts. It is also on account of this that the fissure is so much reduced in length and is often displaced towards the middle line.

(2) <u>The Sylvian Fissure</u> :

This is most characteristic in the microcephalic brain. It has rotated forward and has thus led to a great reduction in the Sylvian angle. It lies usually in the <u>same straight line as the fissure of Rolando</u>, or it may be only <u>parallel</u> to it, according to the relative lengths of these two fissures. Or still more rarely, as it rotated forwards it has been unable to pass the posterior arm of the terminal bifurcation and has pushed the whole of the fissure of Sylvius as well as its bifurcation forwards until it assumes a position at right angles to the normal.

(3) <u>The Island of Reil</u> :

Is small in size and shows either very few or no gyri upon its surface.

(4) <u>The Sylvian Opercula</u> :

Are very feebly developed. The fronto-parietal operculum is usually absent, the temporal is only poorly developed, and overlaps the Island of Reil only to a small extent. The orbital and frontal opercula are usually absent or only slightly developed.

(5) <u>The Fronto-orbital Sulcus</u> :

Is invariably present and well marked. It has long been recognised as a most typical feature of the microcephalic brain.

(6) <u>The Praecentral Fissure</u> :

Is always strongly marked and cuts deeply into the substance of the frontal lobe. It is almost always in the <u>shape of a large Y</u>, and this is to be always looked for and used as a guide to aid in the correct recognition of the fissure of Rolando.

(7) <u>The Superior Frontal Sulcus</u> :

Is always poorly developed, and usually in the form of one or two or three separate elements. These scarcely ever run together to form a large single continuous fissure.

(8) <u>The Intraparietal Sulcus</u> :

Is a most extremely well developed sulcus. It is deep and tends to be opercular. It is a single and continuous fissure which curves round the upper extremity of the temporal sulcus.

(9) <u>The Inferior Postcentral Sulcus</u> :

This has been displaced forwards owing to the growth of the parietal region, and it may, and usually does, ultimately come to coincide with the fissure of Rolando.

(10) <u>The Postcentral Gyrus</u> :

This in consequence disappears. This is the usual condition. As the result of this displacement forwards of the anterior end of the intraparietal sulcus, i.e., the sulcus postcentralis inferior, the ascending parietal convolution is lost. A complete series of intermediate conditions may be found in different microcephalic brains to prove this point beyond all doubt.

(11) <u>The Bifurcation of the Upper End of the Fissure of Rolando</u> :

Is usually present and is due either to the union with the fissure of Rolando, of the superior postcentral sulcus, or the upper part of the inferior postcentral sulcus. This bifurcation may not at first sight be very clearly evident, owing to its outer end becoming continuous with the intraparietal sulcus, and if the inferior postcentral sulcus does not coincide with the fissure of Rolando, this bifurcation is usually absent unless there is a superior postcentral sulcus.

(12) The Bifurcation of the Lower End of the Fissure of Rolando :

This is a most characteristic feature of the microcephalic brain. The anterior arm is clearly the fissure of Rolando itself. The posterior arm may represent either one or both of the two following fissures : the sulcus postcentralis inferior, or the upper part of the first temporal sulcus. If the parietal area has not displaced the inferior postcentral sulcus to such an extent that it coincides with the fissure of Rolando, then this terminal bifurcation is absent. The presence of the upper part of the first temporal sulcus is due to its accompanying the Sylvian fissure when it came to rotate forwards in the manner which I have just described.

(13) The Calcarine Sulci :

Are most characteristic. There is no anterior calcarine sulcus, and a most unusually well-marked and deep posterior calcarine sulcus. The gyrus cunei is usually on the surface and if not is not found at any great depth.

(14) The Parieto-occipital Sulci :

Are also very typical. The two opercula bounding this sulcus are usually only poorly developed, and thus the incisura parieto-occipitalis is found on the mesial border, and the arcus intercuneatus is exposed. This arcus may be so poorly developed that the incisura parieto-occipitalis extends downwards as far as the gyrus cunei.

(15) The Occipital Region :

Is as a whole always so reduced that the cerebellum is usually considerably uncovered.

(16) <u>The Temporal Region</u> :

Is characterised by the separation of both the superior and inferior temporal sulci into their upper and lower constituents and the displacement forwards of this upper element, so that the upper part of the superior temporal sulcus comes to rotate forwards with the fissure of Sylvius and may even unite with the lower end of the fissure of Rolando, and the upper end of the inferior temporal sulcus comes to lie in the same straight line as in the lower end of the superior temporal sulcus . The lower end of the inferior temporal sulcus undergoes very little displacement if the inferior occipital sulcus comes to lie superior to it. If it lies inferior to its posterior extremity, then the termination of this lower part of the inferior temporal sulcus may be displaced forwards.

(17) <u>The Calloso-marginal Sulcus</u> :

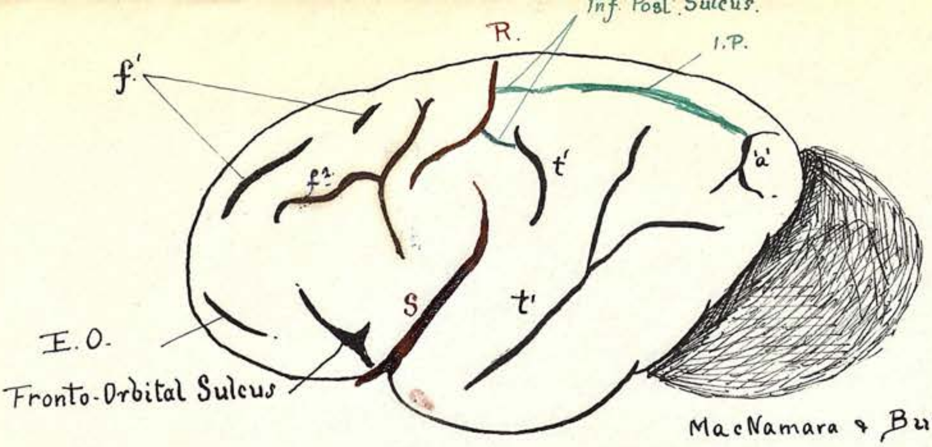
Is usually found in its three separate elements. The posterior is very poorly developed and may be absent. The middle is very prominent and deep, and the anterior is usually most strongly marked.

(18) <u>The Sulcus Collateralis</u> :

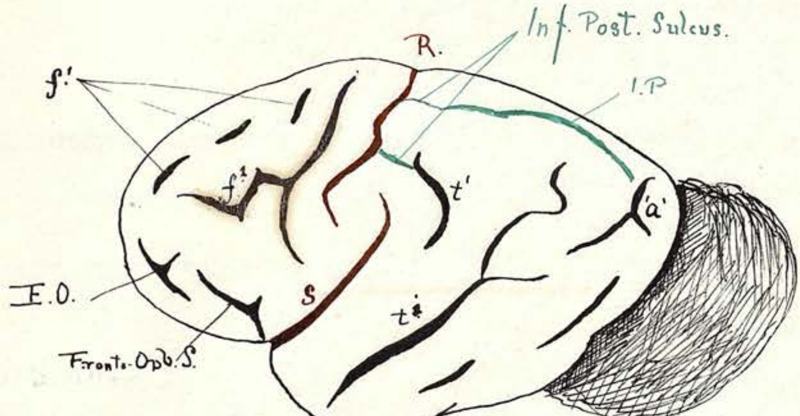
Is also usually separated into its three elements. It may be united into one, with one, usually two prominent deep gyri, and it is usually well marked, there being also a rather unusually prominent hippocampal area.

These above points are all typical of the true microcephalic brain. I have found them in all those cases which I have been able to discover. It may be that one, two or three of them may not quite conform to the above description, but the general aspect of the brain follows the above description. I have here represented what might be considered a "diagrammatic microcephalic idiot brain". It presents all those features which are typical of the microcephalic brain, and all such brains show these points subject to variations within the range of those which I have just attempted to describe.

I wish, therefore, to state clearly that the answer to the theory first laid down by Professor Cunningham that he considers it probable that "microcephalic brains conform to a certain definite morphological type and present a natural group outside the domain of pathology" is in the affirmative. <u>They do conform to a certain definite morphological type and present certain common features which are characteristic of the microcephalic brain and of it only.</u> But in some microcephalic brains, the resemblance is so close that it is remarkable to a degree. This is so in the brain of Robert Lindsay and in that described by MacNammara and Burne (Journ. Anat. and Physiol., 1903).



MacNamara & Burne. (Jour. Anat. & Physiol. 1903)



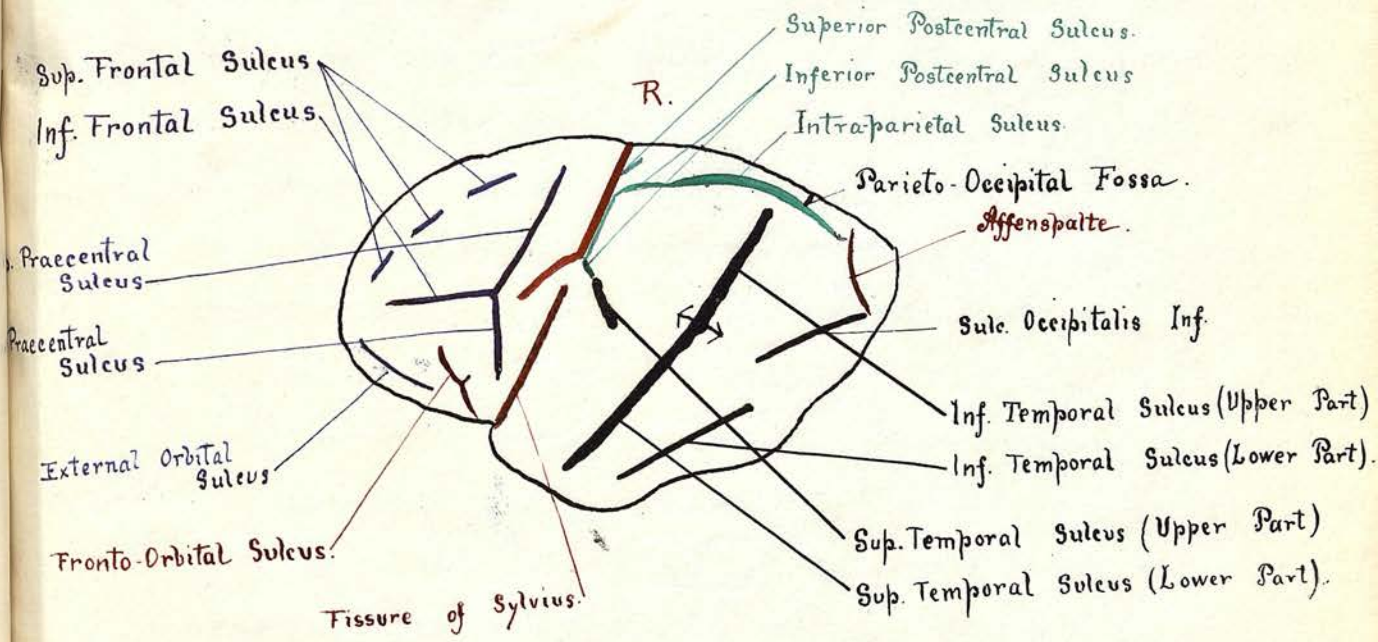
ROBERT LINDSAY.

In these two brains the great reduction in the occipital region is evident; the Rolandic and Sylvian fissures are similarly disposed, the terminal bifurcation is present, the inferior postcentral sulcus is C -shaped and exactly similar in both cases, and so also is the frontal region and the temporal sulci. The resemblance here is almost complete. And all the other microcephalic brains are practically the same. Cunningham has suggested that they may be divided into two types, one where the foetal element is most marked, and one where the simian features are best seen. This is undoubtedly so, but we must not look upon these as being two types. They are really one and the same type. Now I wish to discuss what is the meaning of this repetition and resemblance which I have just shown to be so characteristic of the microcephalic brain.

The following diagram is meant to represent a

"TYPICAL DIAGRAMMATIC MICROCEPHALIC BRAIN",

i.e. the type upon which all true micrcephalic brains may be based.



Explanation of Appearances found in the Microcephalic Brain :

When I later come to discuss the cause which produces this change, I shall go more fully into detail as regards the disturbing influence which has been at work here. This I postpone until I have described the appearance of the spinal cord, where changes of the very greatest importance have occurred. At present I propose merely to deal with the significance and meaning of the changes in the brain.

I have pointed out repeatedly that we find both foetal and simian characteristics on the microcephalic brain, but that there are also present features which are neither simian nor foetal and which are found in this condition and in it alone.

Vogt, who first put forward the view that the condition is to be regarded as an "atavism", considered that a simple arrest of development constituted an atavism, and that if such occurred we could imagine a condition in which an embryonic condition would become stereotyped, as it were, on the brain.

As I have already pointed out, this view is not consistent with the facts which I have just described. The presence of a superficial gyrus cunei, of a fronto-orbital sulcus, etc., and the absence of an anterior calcarine sulcus and of the ascending parietal convolution all point most clearly to the fact that we are not dealing with a simple arrest of development and a subsequent embryonic condition stereotyped upon the brain, since none of the above features are found at any stage in the development of the foetal brain. Indeed, Cunningham has already clearly pointed out that this view is not sufficient to account for the condition here present.

Nor is the condition a direct reversion to an ape-type, because we have here features which are not found on any ape brain. The absence of the ascending parietal convolution, the displacement and rotation of the fissure of Sylvius into the same straight line as the fissure of Rolando, the absence of the fronto-parietal operculum and the extremely feeble development of the temporal operculum are all points which are not found on any known ape brain.

Cunningham explains the condition thus : he believes that the condition is an "atavism", and it is here necessary to understand very clearly what he understands by this term. "An atavism is not simply an arrest of development. Something more is required to constitute an atavism. It is necessary that certain of those ancestral features which are omitted in the ordinary course of development should be reproduced, or that certain of those parts of the phylogenetic history, which in the ontogeny of the individual have become blurred or abbreviated, should reappear in a distinct and intelligible manner. This is what we believe has taken place in the case of the cerebral surface of the two microcephalic brains which we have described. Whether either one or other repeats in its totality the convolutionary pattern which was distinctive of any particular period in the evolution of the stem-form, it is impossible to say, but we are rather inclined to think that neither of them does. Certainly we may exclude the brain of Joe from such a generalisation. The case is different, however, with the brain of Fred. The convolutionary arrangement is more ape-like than human, and it is so consistent in its pattern throughout the whole cerebral surface, that we cannot shut our eyes to the possibility that in it we may have a tolerably faithful reproduction of the gyri and sulci which at one time were characteristic of an <u>early stem-form of man</u>". "We concur with the remark of Giacomini which he applied generally to the brain, viz., that "the microcephalic brain, taken as a whole, always retains the human imprint", but he undoubtedly understates the case when he adds, "It is only in some points of its superficies that we find dispositions which recall those that we met in the brains of certain animals". He comes to the conclusion that in the cerebral surface of microcephalic idiots of high degree one finds besides the signs of developmental arrest other dispositions which constitute "veritable animal resemblances, and which can only be explained as atavisms". He adds, however, that "microcephaly cannot be utilized in favour of the theory of descent, because it represents no historical period in the development of man : it shows us nothing more than what was already known by other peculiarities met with in the human organism". This is a statement which can hardly be accepted as it stands. We have no means, it is true, of being absolutely assured that the cerebral surface of a microcephale ever repeats exactly all the characters of a remote ancestor, but there is reason to believe that in certain cases such an occurrence is not impossible, whilst in the majority of cases some lost convolutionary trait is recovered. If this does not add to the material upon which the theory of descent is built, it at least strengthens the hypothesis, and vastly increases the interest of its applications. Again, the fact that in the arrangement of the gyri and sulci of a microcephale we find a mixture of the characters which distinguish a high ape with those which are characteristic of a low ape, is one which possesses a very high interest and significance in connection with the theory of descent".

This view of Professor Cunningham is quite clear. He considers that the microcephalic brain is an example of an "atavism," comparable to the occasional presence of a supra-condyloid process of the humerus. It represents "a tolerably faithful reproduction of the gyri and sulci which at one time were characteristic of an <u>early stem-form of man"</u>. But it will be noticed that this explanation is not complete since he considers that the brain of Joe does not "repeat in its totality the convolutionary pattern characteristic of this early stem-form". We must therefore come to the conclusion that this explanation is not an absolutely complete one.

Cunningham considers that there has been an alteration in the normal development, so that the brain, instead of passing along the path which will ultimately terminate in the complete fully developed type, passes along a lower and less specialised path which will lead to the production of a type of brain which was found in some early stem-form of man. "The growth disturbance which has given rise to this must have taken place at a period varying from the third to the fourth month of development". Here, I think, we have the most important point of all. If the brain has developed normally up to the third or fourth month, and has then undergone this sudden growth disturbance which has resulted in the production of a lower type of brain, this lower type of brain will be superposed upon the normal three or four months' brain, and thus the resulting condition will represent, not the superposed type of brain, but the result of the mechanical disturbance which must necessarily occur from the superposition and subsequent development of this simpler type of brain upon the normal three or four months' brain. This is, to my mind, the explanation of the condition here present, and it is due to the mechanical disturbance resulting from this change that we find on the microcephalic brain features which are not found on the adult, foetal or ape brain, and which are characteristic of the microcephalic brain and of it alone.

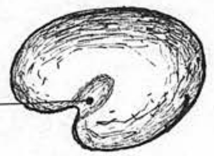
When I speak of the superposed "ape-like" type of brain, I mean that the brain which has resulted from the growth disturbance, has produced on the cerebral surface changes which are analogous to those which would necessarily result if a type of brain resembling that of the lower ape were superposed on the foetal three months. brain, and therefore presumably this superposed type of brain bears a very close resemblance to that of the lower ape type.

In discussing the microcephalic brain from this point of view, it is remarkable how complete an explanation is obtained of all the points which have hitherto been so difficult to understand, and in fact this view explains all the known facts of the whole cerebro-spinal nervous system in such a complete manner that it is difficult to come to any other conclusion but that in, at least, approaches the truth.

I shall now proceed to investigate the whole of the microcephalic brain characteristics (as learned from the examination of a number of such brains) from this point of view.

The first point with which I wish to deal is the fissure of ~~Sylvius~~ Rolando. This fissure is small in size and possesses smooth bounding walls and no deep annectant gyri or buttresses. It presents an appearance similar to that found in the lower ape, where it is also smooth and has no annectant gyri. It has obviously developed in a single part. In man it develops from two parts which ultimately unite to form the continuous fissure of Rolando characteristic of the human adult brain. In the microcephalic idiot, it is the upper of these two elements which has disappeared. And although these two fissures are not seen on the surface of the brain until the sixth month, still the cortex at the third or fourth month is growing along the line which will untimately lead to the production of the two fissures, and if a change occurs and only the lower element develops and the upper one disappears, there will necessarily be a reduction in the amount of cortex at the upper end of the fissure of Rolando, and the fissure will be displaced upwards to take the place of this diminished area. But besides this, there is another point, namely, that when the growth disturbance occurs and the brain develops along this new line, the new type of brain differs from the normal in one very important point : it is very considerably smaller in size as well as simpler in convolutionary arrangement, and therefore the fissures in this superposed ape-like brain will be smaller than those already in process of development. Therefore the fissure of Sylvius in the superposed brain will be correspondingly reduced in size in proportion to the reduction in size of the brain. But owing to the movement upwards of the fissure of Rolando, the mechanical stress set up has affected the cortex at the lower end of the fissure of Rolando, and this has resulted in a rotation forward of the fissure of Sylvius until it reaches the point of least resistance, which is when it lies in the same straight line of the fissure of Rolando. There have thus been two causes at work to produce this : firstly, the developmental disturbance affecting the fissure of Rolando, especially in its upper part, and resulting in a diminution in the cortex of this area, and secondly, the diminution in length of the fissure of Sylvius corresponding to the smaller type of brain. It is these two factors which allow the two fissures to be situated in the same straight line. In addition there is also the factor of the reduction of the Sylvian angle in the ape-brain, and we should therefore expect a corresponding reduction in the microcephalic brain. The Sylvian angle is reduced in the foetus also, but the point to which I specially wish to draw attention is that the reduction in the Sylvian angle is far greater than can be accounted for by either of these two facts, and that we obtain a complete explanation if we regard the condition as a mechanical result of the growth disturbance, as I have just described. We do not always find, however, that the lengths of the two fissures are such as to allow of their being situated in one and the same straight line, and in these conditions they lie parallel to one another, this being the line of least resistence under such conditions. But while these changes are going on, there are also similar alterations occurring in the neighbouring regions, especially in the parietal, resulting in the displacement of the sulcus postcentralis inferior forwards until it comes to coincide with the fissure of Rolando and to form a bifurcation at its lower extremity. And if the length of the fissure of Sylvius be such that it is unable to pass below this posterior arm of the terminal bifurcation of the fissure of Rolando, then it pushes the whole fissure of Rolando forwards until it comes to occupy a position almost at right angles to the normal, and the fact that such a result as this has occurred affords the strongest evidence of how very powerful the disturbance must be which is necessary to produce such a very great change as this.

In the early months of foetal life, however, the fissure of Sylvius is not simply a fissure comparable to the fissure of Rolando. "It is towards the end of the second month of development that the first sign of the Sylvian depression may be detected. At the same time, it is right to state that its appearance is frequently delayed beyond this stage, and I have observed hemispheres well on in the third month with hardly a trace of it" (Cunningham). The Sylvian fissure is due to the "growth projection into the cavity of the hemisphere which forms the corpus callosum and corresponds with the central lobe or insula on the surface, and is not produced by a folding in of the mantle wall, but by an elevation in the floor of the prosencephalon. The surface area corresponding to this internal projection does not keep pace with the mantle, as the latter grows around it, and in consequence the Sylvian depression becomes evident". "At first the Sylvian depression exhibits a nearly circular outline and lies on the outer bean-shaped hemisphere. The surrounding mantle is raised very slightly beyond the level of the surface of the fossa, so that the outline is by no means distinctly mapped out. As the foetus enters the third month, the depression usually becomes more apparent. The surrounding boundary of mantle-wall becomes higher and more evident, the area enlarges, and towards the end of this month it shows a tendency to elongate in the vertical direction and at the same time take a backward inclination.



In the fourth month the elongation and backward bending of the fossa is more marked and now the area is surrounded by a high projecting boundary of mantle wall which limits it in the most definite manner". "Later the arch-like form is lost and the fissure begins to bend backwards". The triangle is established at the fifth month. The opercula develop in the latter half of the fifth month. It is about the third or fourth month that this arrest of development has occurred, and the condition of the cerebral hemispheres at this period is shown in the above figure. It will be at once evident how easy it is for the Sylvian fissure to be affected by any change in the Rolandic region, and such a change will cause the end of the fissure of Sylvius to be drawn towards the diminished area. And once this has happened, the condition cannot be altered, and as the brain develops later this position of the fissure of Sylvius becomes permanent, and is to be regarded as one of the most important features of the microcephalic brain. But the mechanical condition which has caused this and which retains the fissure of Sylvius in this condition will prevent the backward movement of the fissure, and will also hinder the development of the opercula, since the cortex on each side of the Sylvian fissure will be subjected to an entirely different set of conditions. By the rotation forwards of this fissure, the distance from its upper end to the "occipital notch" is greatly increased, and thus will allow of the expansion of the temporal operculum into the temporal lobe instead of over the Sylvian fissure; and in a similar manner the expansion of the fronto-parietal operculum will also be able to take place in an upward direction instead of over the Sylvian fissure as a fronto-parietal operculum. But the sharp boundary which exists between the island of Reil, on the one hand, and the boundary walls of the fissure on the other, is lost and the supersylvian sulcus of Elliot Smith is accordingly absent. The absence of these two opercula is therefore to be looked upon, not as an ape or foetal resemblance, since they are well developed in both, but as the result of the mechanical disturbance caused by the superposition of the simpler ape-like brain upon a foetal brain at this early date. A brain which has already developed as far as the third month is in a condition which allows changes in its substance to take place with considerable ease, since the walls are very thin and the cavities very large indeed in proportion, and if a brain at the third month be examined histologically (and I have done so), it will be found that the layers of the cortex have not become differentiated yet. The cerebral surface is in a state which allows changes of this nature to take place with ease, and once they have occurred the condition becomes necessarily permanent, and is found in a more or less unaltered condition in the fully formed brain. But although I have described the fissures of

Rolando and Sylvius as being in the same straight line, it will now be seen that what has occurred is that the fissure of Sylvius being the only fissure present on the brain at this early period, takes up this position as near the diminished Rolandic region as possible, and when the fissure of Rolando comes to be formed later at the fifth month, in its natural course of development it then comes to take up this position which is the normal Rolandic angle found in the ape and in man.

To summarise the changes here, therefore :-

1. There has been a reduction in the cerebral cortex in the upper end of the fissure of Rolando, associated with an arrest of development and subsequent superposition of a simpler type of brain, in which the fissure of Rolando has only developed in one part, and thus the upper element has dropped out.
2. The neighbouring region is, in consequence, put into a state of stress, which is relieved by the movement of the weakest part of the cortex towards this reduced area, namely the fissure of Sylvius. This fissure is accordingly drawn upwards to this Rolandic area, and when we consider the position of the fissure of Sylvius at this early stage, it will be seen that the actual amount of disturbance is not great.
3. Once the fissure of Sylvius moves into this position, it is retained permanently, and cannot therefore undergo the

usual subsequent backward rotation characteristic of the developing foetal brain.

4. The prevention of the backward rotation has so interfered with the bounding walls of the fissure that the opercula are unable to develop properly, and thus they are either absent or, if present, are only very poorly developed.

5. These changes are not comparable to any known condition found in any of the ape brains or at any stage in the foetal brain. They are only found in true microcephalic brains.

6. They are capable of being completely understood if regarded as the necessary result which would follow if a normally developing brain about the third or fourth month were suddenly to undergo an arrest of development, and subsequently to follow some simpler and less complicated line resembling that of the lower ape brains, the condition here representing the superposition of this latter type upon the former.

If we now follow this view further, we find a complete explanation of all the features of the microcephalic brain.

Cunningham has pointed out that there is a curious mixture of foetal and simian features on the microcephalic brain. After this growth disturbance has taken place, the subsequent development tends to produce the pure simian type of brain, and therefore we find pure simian features present in those regions where the past growth of the hemisphere has not proceeded far enough to affect them. This is well shown in the anterior part of the insula which is exposed in the microcephalic brain. This region is not affected to any great extent by the upright position of the Sylvian fissure and therefore the condition here exhibits the pure ape condition clearly, i.e., there is a well-formed fronto-orbital sulcus. This sulcus is not found at any period in the development of the foetal brain, and thus it is to be regarded as a pure simian character.

There is no evidence here of any mechanical disturbance, because this area does not develop in the foetal brain before the seventh month, and a change occurring as early as the third or fourth month will have come completely into action and will not be altered by any other features which are found in the foetal brain at a period subsequent to this. It is here that we find the explanation of the absence of the sulcus frontalis medius, and of all the other sulci which are found in the normal human brain at a later period. All those which develop late in the foetus are absent in the microcephale, and those which develop about the middle of the foetal life are only found in their embryonic condition. When the growth disturbance occurs, the aim of the brain is to try to reproduce this simplified type, but the already formed normal cortex is in such a condition that as growth proceeds, certain of those normal characteristics are also to a slight extent brought forward. We find evidences of this in the incipient orbital operculum which is occasionally present.

The change which is found in the frontal lobe is, as I have already pointed out, of a most interesting nature. In consists of two factors, one the embryonic condition of the superior frontal sulcus, the other the simian character of the praecentral sulcus. These two quite distinct features are found side by side. The explanation of this lies in the fact that the growth of the frontal lobe has been such as would lead to the normal formation of the separate sulci, as found in the human brain, but when the arrest occurred and the simian characters were superposed on the above, then the praecentral and inferior frontal sulci were formed, and all the other sulci found in the brain of man and absent from the ape brain simply did not develop any further, and are in consequence found in this embryonic state. The frontal lobe, therefore, simply shows the result of the superposition of the ape condition upon the foetal. No mechanical disturbance takes place here at all comparable to that which has affected the fissures of Rolando and Sylvius. The condition in the parietal lobe, however, is of an entirely different nature. Here the difference between the foetal and the ape condition is very great, and there has resulted, not only a superposed ape condition, but also a great mechanical disturbance consequent on this, which has affected the cortex in this region and has led to the disappearance of the ascending postcentral gyrus and the forward displacement of the inferior postcentral sulci and also, when it is present, of the superior postcentral sulcus. This great increase in the rate of growth of the parietal lobe is a very important factor here. The function of the parietal lobe appears to be that of a great association centre in connection with the visual, auditory and motor centres which lie round it (Mott). The first two of these centres are very prominent in the lower ape, and are also very well developed in the microcephale, and there is thus a great development of the association centres in connection with them. And as the visual area, i.e., the streak of Gennari, is limited mostly to the mesial side of the occipital lobe and does not extend to any great degree on to the external surface, we find that the greater part of the posterior Rolandic region consists of parietal lobe only. This varies considerably, however. In some brains the amount of parietal area and frontal area is about equal; in others the frontal area greatly exceeds the parietal, and this is the most common condition. I do not propose again to enter into the explanation of the changes in the parietal lobe ; I have already done so, and have shown that the simple ape-like intraparietal sulcus is one most characteristic feature of the microcephalic brain, and that, being superposed upon a partially developed normal brain it has pushed the anterior sulcus, (i.e. the inferior postcentral) forward until it comes to coincide with the fissure of Rolando, and thus the ascending parietal gyrus is lost. This is not a condition found in any ape brain. It is characteristic only of the microcephale, and is due to the pressure exerted upon this region by the rapidly growing cortex of the parietal region, and is therefore to be regarded as a purely mechanical result.

The occipital region also shows a most typical series of changes which receive a full explanation when regarded from the above point of view. The ape condition is most evident. There is a superficial gyrus cunei and no anterior calcarine sulcus, and the arrangement of the parieto-occipital sulci is also most typical. The condition is obviously just what does occur if we superpose a simple ape-like type of brain upon an early foetal brain, and this explanation so completely accounts for the condition present that it is difficult to come to any other conclusion than that it must approach the truth. The condition here is simply the superposition of the one type upon the other. No great mechanical disturbance has taken place in this region. The chief point is the great reduction in size of the occipital region following upon this change, as a result of which the cerebellum becomes partially uncovered and the occipital region triangular in outline, so that, in the strict sense of the word, there is no "occipital pole".

The temporal region like the parietal, shows two changes, the one due to the superposition of the ape type on the foetal, the other due to the mechanical disturbance so produced. This has resulted in a complete separation and displacement of the parts of the superior and inferior temporal sulci. When the fissure of Sylvius moved forwards, (or as I have shown, it would be a more correct description to say "failed to move backwards") the upper part of the first temporal sulcus retained its position close to the upturned end of the posterior limb of the Sylvian fissure, and may form part of the posterior arm of the terminal bifurcation of the fissure of Rolando. But the lower part of the superior temporal sulcus is formed in its normal position. In the lower ape, the upper part passes directly towards the middle of the intraparietal sulcus, and in the microcephale there is a displacement of the upper part of the inferior temporal sulcus to occupy this space, and we find a strong and prominent sulcus passing from the temporal pole to the middle of the intraparietal sulcus, thus reproducing the condition found in the ape, while the foetal condition is represented by the displaced upper part of the superior temporal sulcus and the presence of the lower part of the inferior temporal sulcus in several separate elements.

I think the evidence which I have now brought forward is quite sufficient to show that the condition of the microcephalic idiot brain is due to an arrest of development, but this in itself is not sufficient to account for all the features present. There has been a further development after this period, and this has resulted in the formation of a simpler brain which bears a very close resemblance to that of the lower apes, but shows many features also which are characteristic of the high apes as well. The superposition of these ape-like characters upon the early foetal brain affords a complete explanation of all the abnormalities in the arrangement and distribution of the fissures and convolutions of the microcephalic idiot brain.

The growth disturbance is said by Professor Cunningham to have occurred at the third or fourth month. With this I entirely agree. But all foetal brains do not always show exactly the same features at the same time. We do not find that the fissure of Rolando appears on the cerebral surface always at one particular date. It is only possible to state that it arises about the end of the fifth or beginning of the sixth month. Consequently if the brain be one in which the various fissures are formed early, and the growth disturbance occur late then the foetal characteristics will be in the ascendency; while if the growth disturbance occurs early and the fissures develop late, then the simian features will be the more prominent We must not, however, consider that the slight differences which are found under these varying conditions represent two different types of microcephalic idiot brains. This is not so. They are simply one and the same type which, owing to the fact that there are two factors at work may result in the one or the other factor being the more prominent. In most cases the simian type is the better marked, and thus the resemblance to the ape brain becomes so apparent. But if it happens that the foetal element is well developed, then it will be found that the condition is not a true foetal state, but an incomplete superposition of the ape-like type upon a more advanced foetal brain than is to be found in the former case.

Therefore I conclude the above description by stating that : The microcephalic brain presents a series of displacements and abnormalities which receive a complete explanation if regarded not as the result of the formation of a stem-form, but as the superposition of a simpler and smaller brain upon a normally developing three or four months' foetal brain, the resulting condition being partly due to the subsequent growth of this simpler type of brain, and partly to the mechanical disturbance caused by its superposition on the normal foetal brain. This simpler and smaller type of brain may be an early stem-form of the brain of man ; there is, however, no doubt that it has a very close resemblance indeed to the lower ape brains of to-day.

Description of the
Spinal Cord

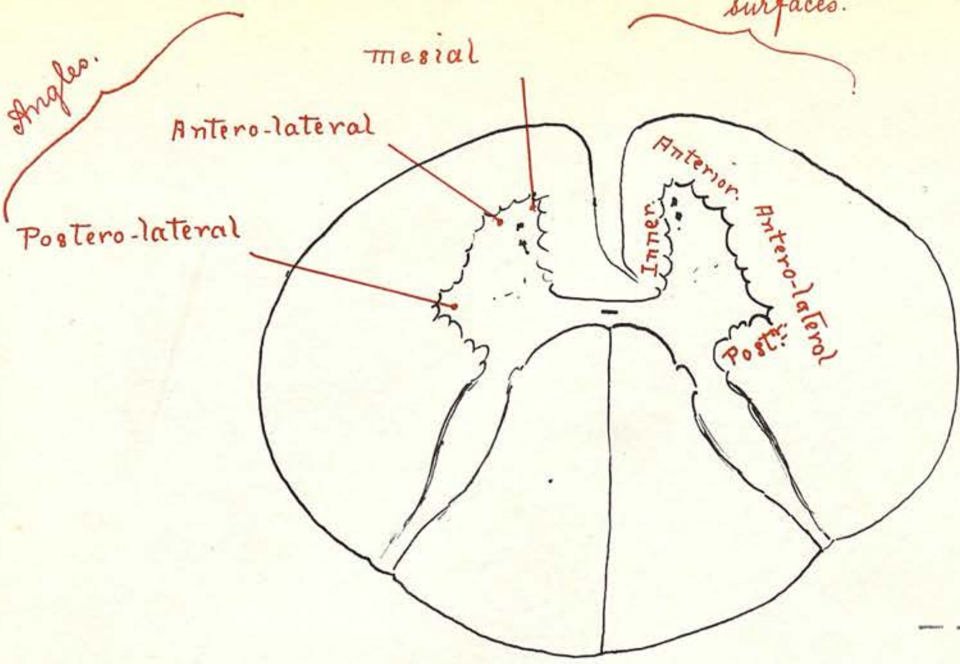
of the

Microcephalic Idiot.

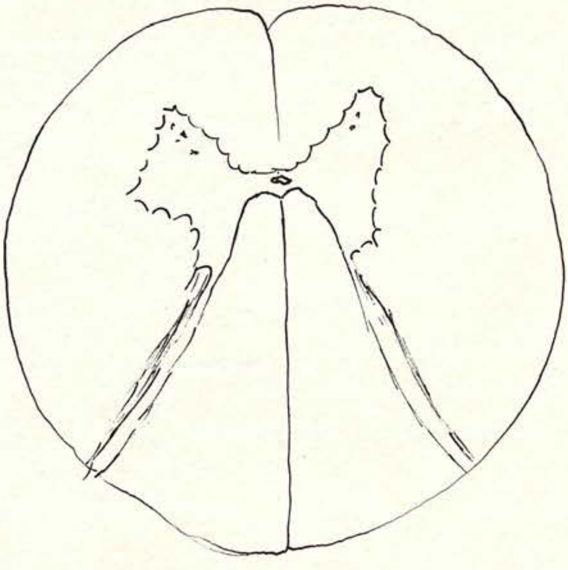
The Spinal Cord.

To facilitate the removal of the cord, it was cut through at the upper level of the third cervical segment, and was placed in formalin, which was evidently very strong, as the nerve fibres round the periphery of the cord have been much altered, especially in the dorsal region. When the cord came into my possession it had been divided into segments, and mounted on small blocks of wood with celloidin. I was thus unable myself to make any observations on the length, etc. of the cord, but there was no doubt that it was very small in size, both in length and thickness. There was no distinct visible vascular change to be noticed.

On an examination of this cord, it is at once apparent that it differs very greatly from the normal, and as this difference is of an entirely different kind in different regions I have considered it best to describe each segment separately. Besides these differences, however, we also find a certain number of characteristics which are found all through the cord, and for which a complete description in one segment will suffice.



Normal.



Microcephale

Third Cervical Segment.

Third Cervical Segment.

A section at this level is almost round, being however, slightly broaded from before backwards than from side to side. The central canal is small, oval and elongated laterally. The posterior median fissure is rather more than twice as long as the anterior median fissure. These two fissures do not, however, divide the cord into two equal halves as the left half of the cord is larger than the right half. The anterior white commissure is narrow; the anterior and posterior grey commissures are equal in thickness and form a curve, the concave side lying dorsally.

As the section was cut in celloidin, the ant. nerve roots after they have left the cord are still retained in position, and differ very markedly from the post. nerve roots. The ant. nerve-ro roots, as a whole, are much diminished in size; the number of nerve fibres is much diminished, their size is smaller than usual, and they do not stain darkly by the Weigert-Pal method. The posterior nerve roots, on the other hand, are large, the fibres stain darkly by the Weigert-pal method, are well medullated and numerous.

White matter:- A section stained by the Weigert-Pal method, (and particularly if counterstained with carmine) does not stain evenly, some parts appearing much darker stained, while others are so feebly stained that they can scarcely be said to be stained at all. The whole appearance resembles that of amylotrophic lateral sclerosis. If examined under a low power, two tracts in particular stand out darkly stained, namely the posterior columns and the direct cerebellar tract. The fibres of these tracts are well medullated, stain darkly and appear well developed. The posterior columns, however, are not evenly stained, since the inner part, i.e., the Column of Goll is less darkly stained than the outer column of ~~Goll~~ Burdach. The anterior white columns are very large and have pushed the anterior cornua to the side so that their inner surfaces, instead of lying parallel to the anterior median fissure, form an angle of about 30° with it. The inner fibres, i.e., the anterior basis bundle is darker stained than the outer part. The rest of the white matter is much lighter stained; the crossed pyramidal tract is small in size; it does not stain darkly and thus is probably not fully medullated. The fibres are small in size and there is an excess of connective tissue between the fibres. Gowers's tract also stains distinctly lighter than the rest and there is presumably also not fully medullated. There is also an excess of connective tissue between the fibres, many of which appear very poorly developed and not closely packed together. This tract is one of the last tracts to medullate, being several months later than the direct cerebellar [1]. Here this difference in staining is so marked that it is possible to tell at once where the division between the two tracts is situated. Staining still more lightly, however, is the tract of Helweg. This tract is situated about the level of the tip of the anterior cornua, and is triangular in shape, the apex pointing inwards. Even in sections of a normal human cord, stained by the Weigert-Pal method, it can usually be detected by its lighter stain. Here, however, it is scarcely stained at all. The number of fibres present is very small and the greater part of the tract consists of unstained connective tissue. It is distinctly larger than is found in the normal cord.

A normal human cord is at this level normal, being broader from side to side than from before backwards. In the microcephale the greater breadth is from before backwards, and this appears to be largely due to the small pyramid tracts and to the great number of fibres in the "anterior" white column, (i.e., the white matter to the interior of the motor nerve fascicles.).

Grey Matter :

It is known that there is a distinctive shape of the grey matter characteristic for each segment of the cervical enlargement, but in the microcephale, although these distinctive characteristics are very appreciably modified, it is still possible to detect them. The microcephalic cord shows two great differences from the normal : the anterior horns have been pushed out laterally so that instead of lying parallel with the anterior median fissure, they form an angle of about 30° with it; and secondly, the greater part of the grey matter of the anterior horn is situated behind the level of the posterior grey commissure, while in the normal cord it is situated in front. In the normal cord (see Fig.), we can distinguish three angles, mesial, antero-lateral and postero-lateral, and four surfaces, inner, anterior, antero-lateral and posterior. In the microcephale the inner surface has been pushed outwards, and thus the mesial and antero-lateral angles coincide, the anterior surface thus disappearing. The antero-lateral surface is almost twice as long as the inner surface and extends far further back than the place of the grey commissure. The postero-lateral angle is rounded and the posterior surface rather shortened. The left anterior cornu is also quadrilateral in shape, but the long axis is at right angles to that of the anterior horn. The posterior horns are small; the formatio reticularis much diminished, and the substantia gelatinosa Rolandi reduced in amount and not shaped, as normally, like a spear-head.

Nerve Cells :

The grey matter at this level contains normally only a few nerve cells, which are arranged in two groups, an antero-mesial group and an accessorius group. But these groups contain in the microcephale only a few cells. These exhibit well-stained Nissl granules, but the cells are distinctly smaller than normal. There appears to be an excess of neuroglia.

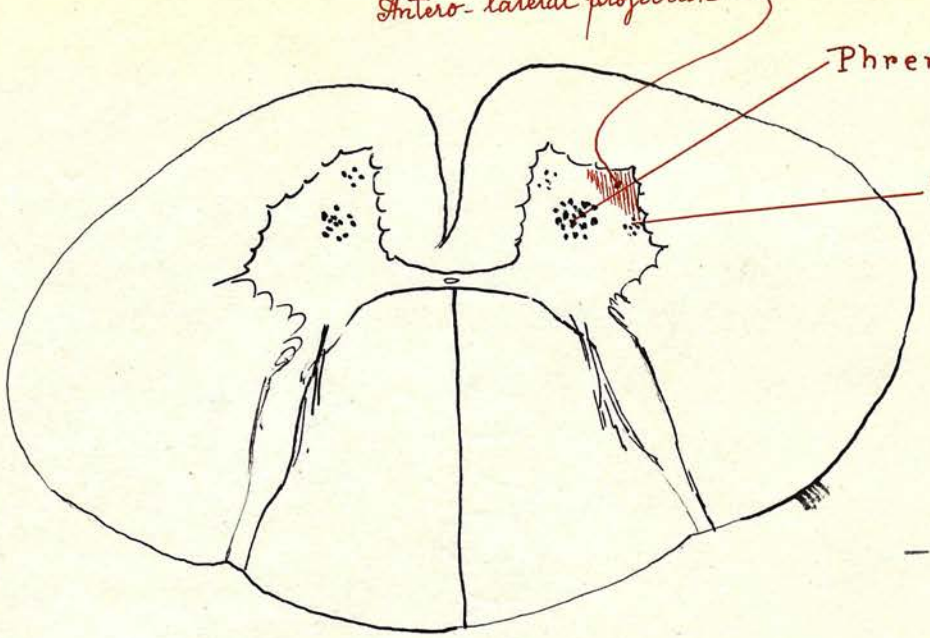
The accessorius group of cells is situated just below the anterior-mesial group, close to the antero-lateral surface. The cells here are also very few in number, and small in size. Well-formed Nissl granules are present in most.

The lateral horn is not found here as a projection, but a small group of cells is to be seen, which are probably those of the intermedio-lateral tract. It is difficult to say whether the "middle cells" of Waldeyer are reduced in number. I am inclined to think they are.

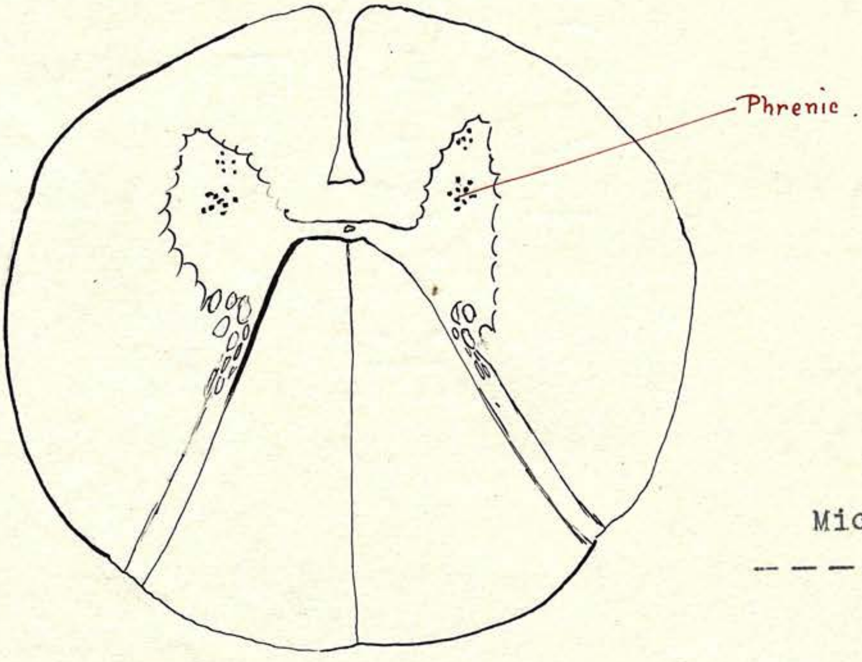
The "cervical nucleus of Stilling" is not present at this level.

Fourth Cervical Segment.

In outline this segment is round; the posterior median furrow is more than twice as long as the anterior median furrow, (longer, in fact, than usual). The anterior and posterior grey commissures are equal in width. The anterior white commissure



Normal.



Microcepha

Fourth Cervical Segment.

is present. The central canal is elongated laterally. The characteristic feature of this segment is the commencement of antero-lateral groups of nerve cells. In the microcephale at this level the antero-lateral group is absent, and the shape of the two anterior cornua does not differ very much from that of the segment above. The posterior column is small, the substantia gelatinosa Rolandi reduced in amount, and its characteristic lancet shape is lost.

White Matter :

This is very similar in appearance to that found in the segment above. The posterior columns are well developed, the column of Burdach again staining much darker than the column of Goll. The direct cerebellar tract is now altering its position and changing from a compact tract to a narrower one lying along the outer surface of the lateral aspect of the cord. The crossed pyramidal and Gowers's (especially the latter) stain lightly, while Helweg's triangle is again almost unstained, but much smaller in amount than in the last segment.

Grey Matter :

To understand the alteration in shape of the grey matter at the different levels of the cervical enlargement, it is necessary to understand the arrangement of the groups of nerve cells, as the alteration in shape is due to the adding on of these groups of cells.

The antero-mesial group is found throughout all the length of the cervical enlargement, reaching a maximum at the fourth and fifth cervical segments where the phrenic nerve is situated, and again at the eighth segment. The postero-lateral groups first appear at the lower part of the fourth segment, and reaching a maximum at the fifth and sixth segments, forms a prominent postero-lateral angle. It then diminishes at the seventh segment, but increases again at the eighth, the postero-lateral projection varying accordingly. It disappears in the first dorsal segment.

The post-postero-lateral group commences at the eighth cervical segment and ends at the first dorsal.

The antero-lateral group, however, appears as two groups, an upper and a lower, the upper beginning in the fourth segment and extending as far down as the upper part of the seventh, forming the marked antero-lateral projection. The lower group begins at the sixth segment and extends as far down as the eighth segment. Thus it will be seen that the two groups, upper and lower, are both present side by side at the sixth segment.

In this microcephale we find that the upper antero-lateral group of cells is wanting, and hence the projection is not marked.

Nerve Cells :

The antero-mesial group at this level is very large, due to the presence of the phrenic nucleus. The antero-mesial group contains fewer cells than normal. Here they seem to have been compressed laterally, as the long axes of the cells lie parallel to the inner surface of the anterior horn, just as if the anterior horn had been pushed outwards and the cells situated close to the inner margin thus compressed.

The phrenic nucleus is situated to the dorsal side of the above group. The cells here, although they contain well-stained Nissl granules, are small in size and undoubtedly few in number, and may vary from three or four up to eleven, while seventeen to twenty is a usual number.

The accessorius group of cells is situated just behind the antero-lateral angle and the cells again are small and do not stain well.

The postero-lateral group of cells is represented by two or three cells close to the postero-lateral angle.

The intermedio-lateral tract is absent.

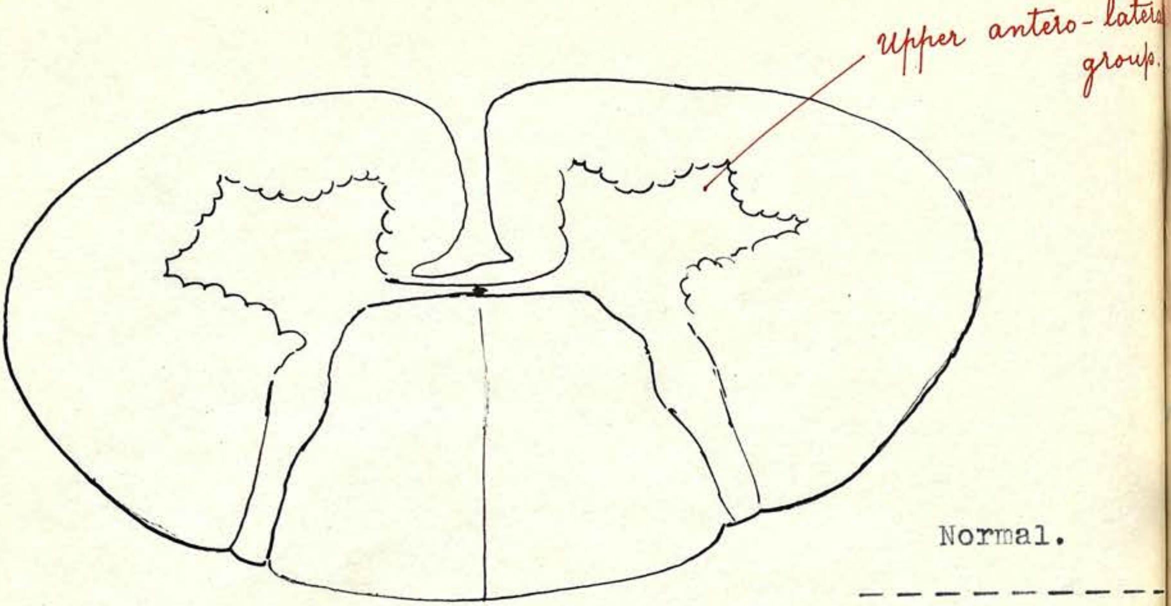
The middle cells appear to be diminished in number.

The cervical nucleus of Stilling first appears at this level and is represented only by from one to three cells in each section. Of these one is normal with well-stained Nissl granules and a central nucleus, while the other two have only Nissl granules round the periphery of the cells; the centre contains none, and the nucleus is excentric and causes a bulging on the wall of the cell.

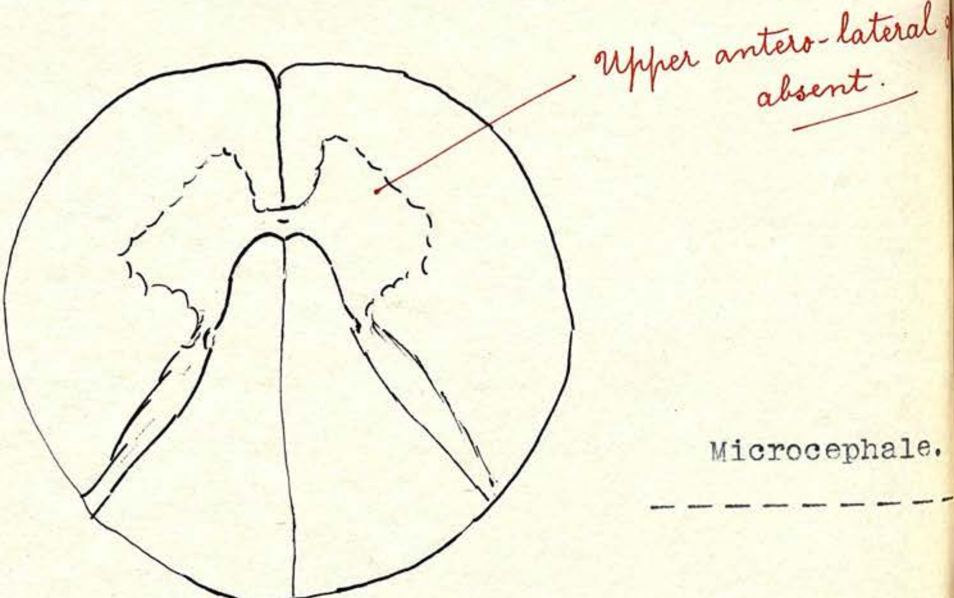
Fifth Cervical Segment

This segment is larger than the last, and is rather wider from side to side than from before backwards. The anterior median fissure is half as long as the posterior median fissure. The anterior and posterior grey commissures are equal in thickness. The central canal is elongated laterally. The left side of the cord is again larger than the right and more than half of the grey matter is situated behind the level of the grey commissure. The anterior-lateral projection is absent, but the posterior lateral projection is present.

Fifth cervical segment.



Normal.



Microcephale.

White Matter :

Weigert-Pal sections at this level resemble those of the last. On the right side the great development of fibres in the "anterior white column" is not so marked, and thus the inner surface of the anterior cornu is parallel to the anterior median fissure. On the left (i.e. larger side), the anterior white column is still large and the inner surface of the anterior horn is again oblique. The width and straightness of the grey commissure which is characteristic of this segment is lost in the microcephale, the commissure being short and curved as if it had been pushed ventrally by the posterior columns.

Grey Matter :

Again in this segment do we find the antero-lateral projection wanting, and as the postero-lateral projection is well-formed we find a straight line passing from the tip of the horn to the postero-lateral angle, which is not sharp but blunt and rounded. The posterior horn is small, and the substantia gelatinosa Rolandi reduced in amount.

Nerve Cells :

The antero-mesial group is represented by from four to ten small cells, (normally fifteen to twenty).

The antero-lateral group appears at first sight to be absent, but on a closer examination it will be seen to be represented on the one side by about ten cells, all small in size, with not well-stained Nissl granules and nuclei which, although they do not occupy the centre of the cell, do not cause a bulging of the wall outwards. On the other side we find an extremely interesting condition. The nerve cells of the upper

antero-lateral group are not really absent. If this group is examined with a low power, a number of lines will be seen to occupy the places where we should expect to see the cells, and on examining these short rods or lines with a high power, we find that they really are nerve cells so small reduced in size that at first sight they are scarcely noticeable. Under a high power these cells show a nucleus, mostly very much flattened from side to side, while the cell itself has been so compressed and narrowed that the interior of the cell has become almost obliterated.

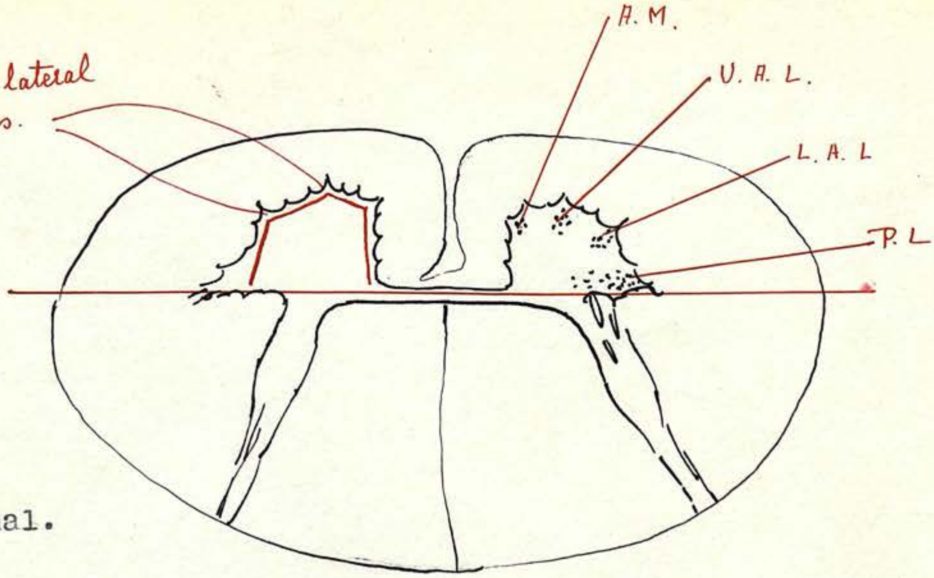
Still, however, the nuclei are in the centre of these atrophied cells, and Nissl granules are to be detected in most, so that the cells are still alive. We are dealing here with a case of muscular atrophy of an entirely new kind - namely a selective muccular atrophy, where only this one group has been picked out. The lower antero-lateral group does not show any similar changes; they are limited to the upper one. We shall discuss this further later.

The postero-lateral group of cells is specially noticeable for the few cells present compared to the normal, and there has not only been a marked reduction in the number of cells, but also in the size of those left, more than half of which are very small. The amount of neuroglia is increased, and the cell-processes are probably poorly developed. Nissl granules are present in most, but in many of the cells, especially the smaller ones, the granules are extremely small. The nuclei are mostly central in position, but do not stain clearly, although the nucleolus stands out very prominently.

The intermedio-lateral tract is present at this level.

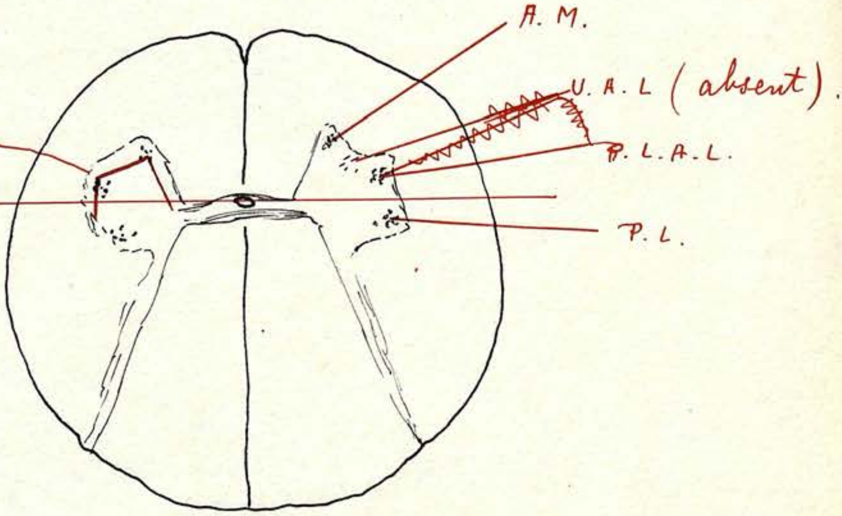
Sixth Cervical Segment.

Note. 2 antero-lateral angles.



Normal.

Note 1 antero-lateral angle.



Microcephale.

Note also position of grey matter in relation to grey commissure. — displaced dorsalwards —.

The lateral horn is not well developed, and the cells are thus mostly situated in the white matter, into which they pass a considerably way. They are very typical normal cells, with Nissl granules and a central well-formed nucleus.

Clarke's column, (i.e., the cervical nucleus) is represented by as many as six cells on either side, none of which are quite normal. The nuclei are mostly round and central, but the Nissl granules do not stain well, and are small in size, especially towards the centre of the cell. 

Sixth Cervical Segment

A section through this segment is not quite round, the lateral diameter being still rather larger than the antero-posterior. The left side is also more strongly developed than the right. This is in very striking contrast to the oval shape of the normal cord at this level, where the cord is almost twice as broad as it is thick. The microcephalic cord is actually thicker from before backwards than the normal cord, although it is very much reduced in width. The anterior median fissure is slightly less than half the length of the posterior median fissure. The central canal is elongated laterally. The anterior commissure of white matter is narrow. The anterior and posterior grey commissures are equal in width and are rounded with the concavity pointing posteriorly, thus giving the appearance of having been pushes forwards. The right commissure is longer than the left, due to the right crescent of grey matter being pushed out further by a larger development of the posterior columns of white matter on that side.

White Matter :

The posterior columns are again strongly developed, the fibres staining darkly. The crossed pyramidal tract is feebly medullated and stains lightly. The direct cerebellar tract is well developed, stains darkly, the fibres being strong and well medullated. Gowers's ascending tract stains lightly, and is clearly not fully medullated. The anterior basis bundle is also darkly stained.

Grey Matter :

Here slightly over two-fourths of the grey matter is situated above the plane of the central canal. The form of this segment is very distinct in the normal cord. The upper and lower antero-lateral groups of nerve cells are both ~~fused~~ present, and hence we find two antero-lateral angles. In the microcephalic cord the upper group of cells is also wanting in this segment, causing an absence of the first antero-lateral angle, while the lower group is present and causes a prominent second antero-lateral angle. The postero-lateral angle is wider and more rounded than the normal.

About three-fourths of the grey matter is situated above the plane of the commissures. The inner surface is nearly parallel to the anterior median fissure. The anterior surface passes outwards making a little more than a right angle with the inner surface, while the lateral surface makes a similar angle and is slightly longer than the inner surface. On the posterior surface there is a slight projection representing the lateral horn, found only on the lesser side. The posterior horn simulates the normal appearance, being thicker about its middle, but it does not diminish much towards its posterior termination. It is interesting to note that between the antero-mesial and the second antero-lateral groups we find a hollow in the grey matter, staining darkly and on high power showing groups of nerve fibres passing up and down and through it, representing the place where the upper antero-lateral group has been picked out. Some atrophied cells are also to be seen.

Nerve Cells :

The antero-mesial group is not well developed; in many sections no cells are present, while in others the cells are small in size and in number. The group is situated at the tip of the antero-mesial horn. The cells may number up to six, and are mostly flattened laterally.

A very few cells belonging to the upper antero-lateral group are present, quite similar to those described and figured in the last segment.

At the antero-lateral angle we find the commencement of the lower antero-lateral group. The cells are not very numbrous, but they stain well, showing large Nissl granules.

The postero-lateral group is specially remarkable for the extremely few cells present. In some sections only five to ten are to be found when normally we should expect from thirty to forty. Those present are also markedly reduced in size, and show various stages leading up to what we have seen had occurred in the upper antero-lateral group. A few cells have completely degenerated; the nucleus has disappeared and the cells have a vacuoled appearance.

No cells in Clarke's column.

No intermedio-lateral tract.

Middle cells seem to be diminished, but it is difficult to be certain of this point.

Seventh Cervical Segment.

This segment is much wider from before backwards than from side to side. The two sides are also not equal, as we have already noted in the upper segments. This is in marked contrast to the normal cord, which is oval, but it must be remembered that although the normal cord is usually oval at these levels, there is also a normal variety which tends to be more rounded. Still the difference is noticeable.

The anterior median fissure is about half the size of the posterior median fissure. The central canal is circular. The anterior and posterior grey commissures ~~and~~ are not thick and are of equal width. The anterior white commissure is well marked.

hite Matter :

Here again the tracts of the posterior columns are strongly developed, well medullated, and stain darkly. The antero-lateral columns are slightly stained. The direct cerebellar tract is well developed; the fibres are large, strong and well medullated, and the whole tract is well marked off from the surrounding tracts. The tract of Gowers stains feebly. It is not well medullated and under a low power is well marked out. The crossed pyramidal tract is feebly medullated, stains very lightly, and the fibres are small and thin. Helweg's triangle has disappeared.

The anterior white columns are still much larger than usual, but the anterior cornu has not been pushed outwards to such an extent as we found in the higher segments.

Grey Matter :

The form of the grey matter here resembles the normal shape more than we have found in any of the above segments. The greater part of the grey matter is situated anterior to the plane of the grey commissures; the horns are slightly curved as they pass outwards, due possibly to the development of the posterior columns. This level is specially characterised by the great development of the lower antero-lateral group of cells, which we saw began in the last segment. It reaches its maximum at this level. The antero-mesial group is not well developed here, and the postero-lateral has not reached its maximum yet.

The inner surfaces of the anterior horns are nearly parallel to the anterior median fissure. The anterior surface slopes upwards to the antero-lateral angle, due to the great development of its groups, is rounded. The lateral surface is slightly concave and the posterior angle is fairly sharp as the postero-lateral group is not very large at this level, The grey matter is also characterised at this level by the large amount of nerve fibres passing through it in small wedge-shaped groups. The amount in neuroglia is increased.

Nerve-Cells :

The anterior mesial group at the mesial angle consists of only a few cells of very small size, but showing Nissl granules.

The postero-mesial group consists of a few cells of small size. Scattered over this part of the grey matter are a number of small cells, most of them elongated and going parallel to the inner surface.

The lower anterio~~r~~-lateral group causes a very marked projection, but its number of cells, though large, is not nearly equal to what we find in the normal cord. The most I could count in one was twenty-five. All are small, some laterally compressed and showing various degrees of degeneration. In the upper part of this level the tendency is for the antero-lateral angle to be narrow and to project far out, while towards the lower part of the segment this projection becomes more blunt and short.

The postero-lateral group here is not so well marked as the lower antero-lateral group. In some sections it consists of only four to five cells. They show similar appearances to those already described.

Very few cells are to be found in Clarke's column at this level.

The intermedio-lateral tract is absent.

The middle cells are also probably diminished in number.

Eighth Cervical Segment

The eighth cervical segment shows the same characteristic shape as the seventh. It is oval with the longest diameter antero-posteriorly. The left half is again larger than the other.

The anterior and posterior grey commissures are thin and raised in the centre, forming an arch. The central canal is oval laterally. The anterior white commissure is well marked.

White Matter :

The appearance of the white matter in this segment is so similar to that of the last segment described that it is almost unnecessary to describe it separately. The same tracts are affected'

Grey Matter :

In a normal cord at this level we find that there is a marked difference between the upper and lower parts of the segment. In the upper part the antero-lateral group is well and prominently developed, but it disappears about the middle of the segment. The postero-lateral group is well developed all through. The post-postero-lateral group begins at this level, increases as we pass down, and forms the only group present in the first dorsal segment.

In this segment the microcephale does not differ very much from the normal, unless for the fact that it is much longer antero-posteriorly compared with the lateral diameter. The inner surface is short and nearly parallel to the anterior median fissure. The anterior surface passes upwards and outwards. In the upper part the antero-lateral angle is sharp and prominent, the outer surface is concave, and the posterior angle is rounded. The posterior surface is straight. The posterior quarter of the grey matter is situated behind the level of the central canal.

The antero-mesial group contains a few cells at the upper level,and none lower down where it increases very markedly.

The antero-lateral group is well developed in the upper part of this segment and disappears as we pass down. The cells are fairly numerous, tend to be small, but contain numerous Nissl granules. In the upper part of the segment where this group causes a very marked protuberance, the cells are not nearly so numerous as we should expect to find in a normal cord.

In the upper part the postero-lateral group is small and increases rapidly as we pass down. In the lower part almost the whole of the protuberance is due to it. It is again characterised by the relatively small number of cells, which show the same characteristics as those I have described in the lower antero-lateral groups.

The post-postero-lateral group just begins at this level, and it is also reduced in number, size and character of its cells The cells are smaller than those of the postero-lateral group.

Clarke's column (i.e. the cervical nucleus of Stilling) is represented by a few cells, most of which are not normal.

The nucleus is excentric, projects from the surface, and the nucleolus is well marked. The centre of the cells has no Nissl granules, stains faintly, and has a vacuolated appearance. Round the periphery of the cells Nissl granules are present. Some normal typical round cells are also present, which curiously are usually of a smaller size than the degenerated ones. A few normal intermedio-lateral tract cells are present in the usual position.

The middle cells do not call for any remarks, except that they appear rather fewer in number than usual.

First Dorsal Segment

Since this segment has more affinity both on anatomical and physiological grounds with the cervical region than with the dorsal we shall consider it here.

In the normal cord at this level both the antero-lateral and the postero-lateral groups are absent, while the post-postero-lateral group here reaches its maximum and thus causes a large projection, which is separated from the tip of the horn by a well marked hollow.

In the microcephale, the post-postero group extends down to this level and causes a projection in the typical position, but the projection is not nearly so marked, and as the postero-lateral group has extended rather further down than usual, extending in fact as low down as the post-postero-lateral group does, the outline of the grey matter is thus characterised by the absence of this hollow. The inner surface of the anterior cornu slopes out obliquely from the antero-median fissure. The postero-lateral group is represented by about eight to ten cells; the post-postero-lateral by about the same number.

The intermedio-lateral tract is present, and a lateral horn is developed. On the right side it is situated on the level of the grey commissure, while on the opposite side it has been pushed so far backwards that it lies as far behind the grey commissure as the tip of the anterior cornua is in front. The two masses of grey matter are thus very different on the two sides of the cord. In the one side the position closely resembles that found in man ? while in the other the grey matter has been pushed backwards. The side in which the grey matter is situated so far dorsalwards lies much nearer the central canal than the other; in fact the connecting straight part of the commissure on this side is only half of the length of the other. The ~~long~~ left cornu is the normal one.

Clarke's column is present; the cells are small, full of Nissl granules, and about four or five in number in any one section.

The substantia gelatinosa Rolandi is reduced in size.

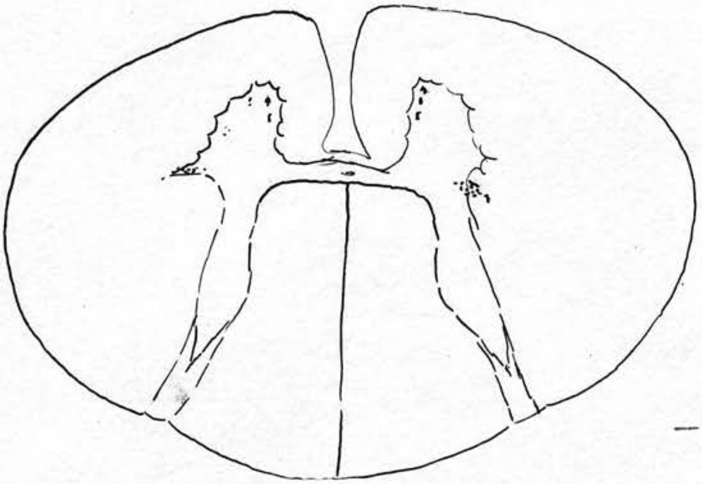
The most striking part of the white matter is the great increase of fibres in the antero-mesial column, which is thus much wider than usual. The margin is not rounded, the two lips of the antero-mesial fissure being close together during their whole length.

Second Dorsal Segment

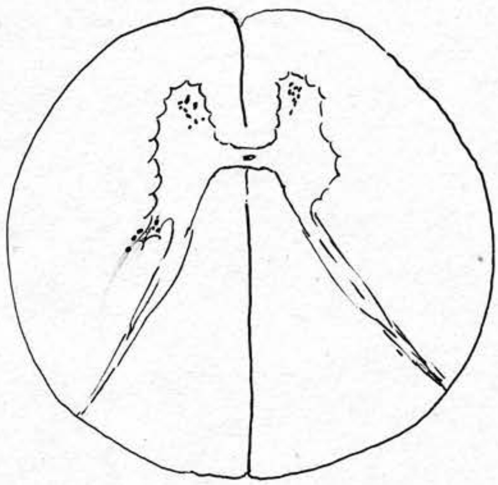
The outline of this section is almost circular. The posterior median fissure is twice as long as the anterior median fissure. The central canal is oval in shape. The general appearance of this section agrees very closely with that normally found at this level. The left side of the cord, however, is markedly larger than the right. It is very striking at this level to note the difference between the anterior and posterior nerve roots. The anterior are few in number and poorly medullated, while the posterior roots are quite twice as large, and well medullated and deeply stained.

White Matter :

Second Dorsal Segment.



Normal.



Microcephale.

White Matter :

The same appearance is to be seen here as in the previous sections. The posterior white columns are well medullated, darkly stained and large. The direct cerebellar tract is also well marked, while Gowers's tract is feebly medullated and does not stain so darkly. The pyramidal tract is small and poorly medullated, and shows an excess of connective tissue between the fibres, this being specially marked first at the margin of the direct cerebellar and the pyramidal tracts.

The lateral basis bundles, or rather the "anterior white column", i.e., the part of the white matter situated mesial to the anterior cornua, is very large, especially on the left side.

Grey Matter :

This resembles the normal grey matter in form, especially on the left side, but on the right (i.e. the smaller) side, half of the grey matter is situated behind the level of the central canal. The inner border of the anterior horn slopes outwards, as if the great development of the anterior horn had pushed it out.

The anterior mesial group is represented by about six cells which are quite normal, except for a curious flattened appearance, as if they has been compressed laterally. The nucleus is central and round, and Nissl granules are present.

A few cells of the antero-lateral group are still present.

Clarke's column is represented by a few small cells, which stain darkly and well. A few cells, however - and it is remarkable that these cells are larger than the others - do not show the same distinct staining; the Nissl granules are

limited to the periphery of the cell, and the nucleus is excentric and tends to become oval rather than circular. The axis of the cells of Clarke's column is parallel to the inner border of the posterior columns.

The intermedio-lateral tract is quite normal in position; the cells do not seem to be very numerous, but they are normal.

The "middle cells" seem to be reduced in number.

Third Dorsal Segment

A section at this level is also almost circular. The anterior median fissure is about half the size of the posterior median fissure. The central canal is elongated laterally. The anterior nerve roots again appear very small when compared with the posterior, which are large and well marked.

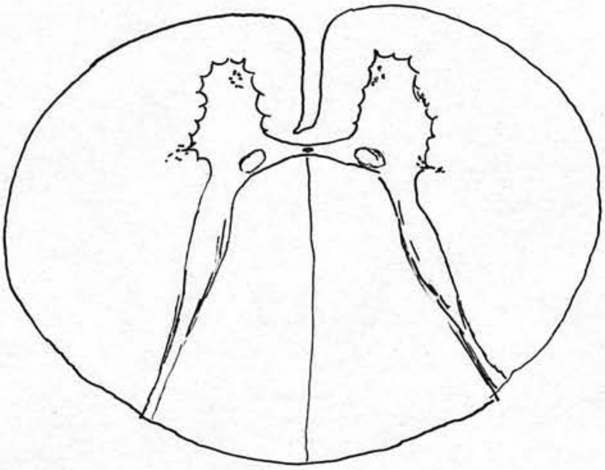
White Matter :

This does not differ very much from that described for the last segment. The left side of the cord is distinctly larger than the right.

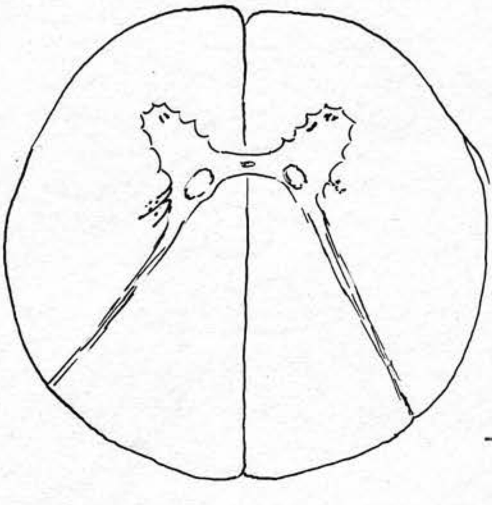
Grey Matter :

The grey matter differs from the normal principally in the peculiar outward displacement of the anterior cornua, the inner surface of which forms an angle of about 45° with the anterior median fissure. (As this is increased at the lower levels, we shall postpone the discussion of its cause till then). The appearance, however, is just as if the whole anterior cornua had been rotated 45°. The motor cells in the anterior cornua are present, and show the same appearance of lateral compression which we saw in the last segment. The nucleus

Fourth Dorsal Segment.



Normal.



Microcephale.

is still central and the Nissl granules well marked. The cells are small, but are not degenerated.

Clarke's column cells are rather more numerous than in the last segment. The great majority are small, round, and full of Nissl granules, while a few - and again these are larger than the others - show the same appearances which I have described for the last segment, namely, Nissl's granules arranged round the periphery, nucleus excentric, etc.

The intermedio-lateral tract is normal, but a few of the cells seem to be rather degenerating. The lateral horn is quite normal in position and development on the left side, whilst on the other it is situated some way below the central canal. The distance at which some of the cells are placed amongst the white matter is remarkable.

Fourth Dorsal Segment

The general characteristics of this segment do not differ much from the last. The anterior median fissure is half the length of the posterior median fissure. The central canal is elongated laterally backwards. The asymmetry of the two sides is very marked. The arrangement of the white matter is similar to the last segment, except that the amount in the "anterior" white column is still further increased, and the anterior cornua of grey matter is also pushed out still further.

The nerve cells are very few in number and small in size, and show the same flattened appearance parallel to the inner surface, of the anterior cornua, as if the same cause which pushed out the anterior horn had affected them also. The cells at the tip of the horn (i. e., the antero-mesial group) are not compressed, but are normal. They appear poor in processes and there is an excessive development of neuroglia cells.

Clarke's column cells are all quite normal. The position of the long axis of the cells is the same as we find in the normal cord, but it is significant that owing to the turning of the anterior cornu outwards, the long axis of Clarke's column comes to be at right angles to the axis of the anterior cornu, which is the condition in the anthropoid apes; but we shall discuss this later when we have seen the position of this group throughout the whole length of the cord.

The intermedio-lateral tract is quite normal; the lateral horn is distinct and large numbers of the cells are situated out in the white matter. Owing to the difference between the two sides of the cord, the position of the lateral horn varies, since on the one side the greater part of the grey matter is situated behind the plane of the central canal, as we saw was the case in the last two segments. On the other side, the lateral horn is situated at the level of the grey commissure. The posterior horns are small, the substantia gelatinosa Rolandi being much reduced in size. Lissauer's tract is also small.

Fifth Dorsal Segment

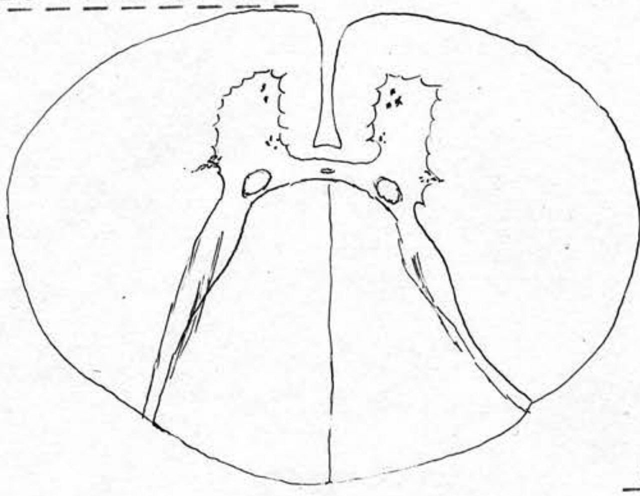
This segment is nearly circular in outline. The posterior median fissure is nearly twice as long as the anterior median fissure. The central canal is elongated laterally. The white matter resembles that of the last segment, except that the anterior white column is still further enlarged, and thus the anterior cornua of grey matter is pushed out still further from the median line. The posterior columns of grey matter are much reduced and the substantia gelatinosa Rolandi is small in amount. The motor cells in the anterior cornua are small in size and number. Those near the inner surface, i.e., the postero-mesial group, are mostly compressed laterally, while those of the antero-mesial group appear to have escaped this lateral compression as they resemble the typical state more. The middle cells are also reduced in number. The lateral horn is quite as large as normal, and the intermedio lateral tract is well developed.

<u>Clarke's column</u> :

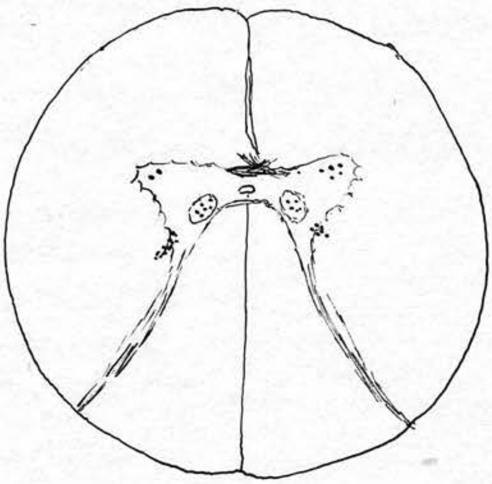
The lower part of the grey commissure and the inner margin of the posterior cornua form an arc of a circle, or perhaps better an arch, while in the normal cord the condition is thus . This difference is probably due to the pushing back of the anterior cornua and the consequent rounding off of the sharp angle (and possibly also to the development of the posterior white columns). Clarke's column, however, is situated in similar positions in both cases, and the position of the long axis of the cells is shown in the figure.  This appearance is exactly similar to that found in man. As in the last segment, however, the longitudinal axis of the anterior cornu in this place is at right angles to this and not at an oblique angle as we find in the normal.

Cells of Clarke's column are small and normal, with well-stained Nissl granules and a central nucleus well stained. No

Sixth Dorsal Segment.



Normal.



Microcephale.

large cells with an excentric nucleus, such as we found in the "cervical nucleus" occur at this level, all the cells being normal.

Sixth Dorsal Segment

This segment is round in outline, also again asymmetrical. The posterior median fissure is two and a half times the size of the anterior median fissure. The central canal is elongated laterally, and is not in the centre of the grey commissure, but has been pushed towards the smaller side. The most characteristic feature of the segment is the extreme degree to which the anterior cornua have been pushed aside, as the inner margin of the anterior cornua is situated in the same straight line as the anterior margin of the grey commissure. This gradual passage outwards of the anterior cornua of grey matter reaches its maximum at this level. The appearance is as if the inner part of the grey matter had simply dropped out, as might occur from an absence of the antero-mesial group of cells, but this is not the case. This group of cells is present throughout the whole dorsal region and occupies a corresponding position in the anterior horn. The whole of the anterior cornua of both sides becomes thus pushed behind the level of the anterior grey commissure. The position of Clarke's column is best seen in fig. ; it lies in a position corresponding to that found in man.

The lateral horn on both sides has been pushed very far back, lying to the outer side and behind Clarke's column. The cells of the intermedio-lateral tract are normal.

The posterior horns are extremely attenuated, the substantia gelatinosa Rolandi being much reduced in size.

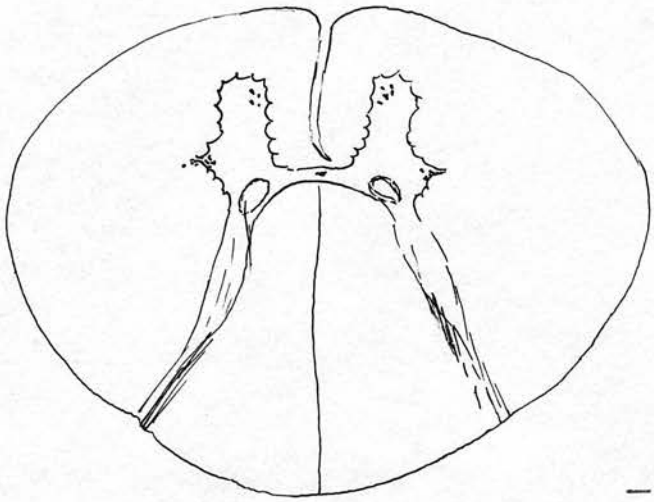
Seventh Dorsal Segment

This segment is round in outline. The anterior median fissure is about half as long as the posterior median fissure. The central canal is elongated laterally and is situated to the right of the middle line, so that from the central canal to the base of the anterior cornua on the right side in only half as long as on the left. Associated with this is the far greater size of the left side of the cord.

The shape of the grey matter in this segment is very peculiar (see fig.). On the greater side the anterior cornu is larger than in the last segment. The inner surface is again oblique. The lesser side, however, has completely and suddenly altered in shape; the missing part of the grey matter has partially appeared, and the shape of the anterior horn on this side resembles that of a normal cord, except that the antero-mesial group of cells remains in its old position, and is thus situated in the middle of the grey matter and not at the antero-mesial aspect. The upward extension of this horn is short, and the upper margin is broad and irregular.

The cells of Clarke's column are becoming more numerous, and are small and all stain well. The group is situated close to the base of the posterior horn, so that the long axis is nearly

Eighth Dorsal Segment.



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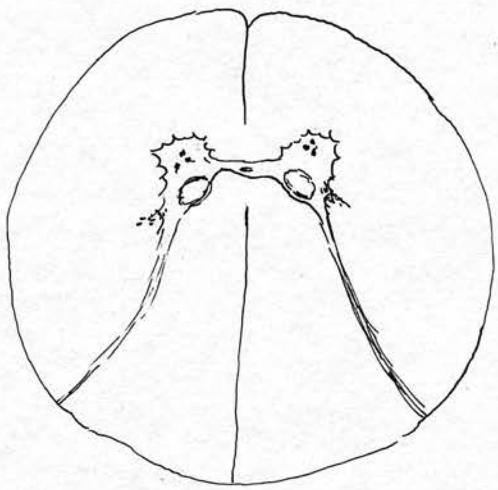

Microcephale.

parallel to the posterior median fissure.

The intermedio-lateral tract is normal.

The motor cells are few in number and small in size. Their position is in the centre of the anterior horn, and not in the antero-mesial angle. Their shape appears altered, as if they has been compressed in various directions.

The posterior cornua are again small, the substantia gelatinosa Rolandi being much reduced in amount.

Eighth Dorsal Segment

This segment is nearly round. The posterior median fissure is twice as long as the anterior median fissure. The anterior and posterior grey commissures are equal in breadth. The anterior white commissure is thin. The central canal is elongated laterally.

The white matter exhibits the same changes that we have seen previously in the upper segments, the large mass of the anterior white columns being specially remarkable. The grey matter of the anterior horns is gradually assuming a shape more characteristic of the normal cord, the two cornua gradually approaching the anterior median fissure again. The motor cells in the anterior cornua are not normal in position, but are arranged rather irregularly through the anterior cornua of grey matter. They are small in size and diminished in number, but show large and very well marked Nissl granules. A great part of the anterior horn is still situated behind the level of the grey commissure.

Clarke's column is in a position similar to that found

Ninth

~~Tenth~~ Dorsal Segment.

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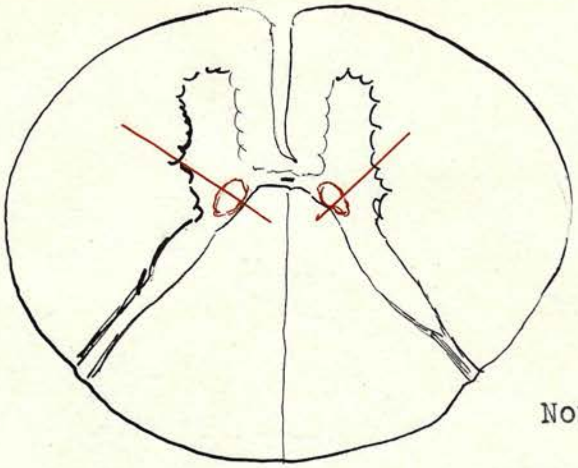

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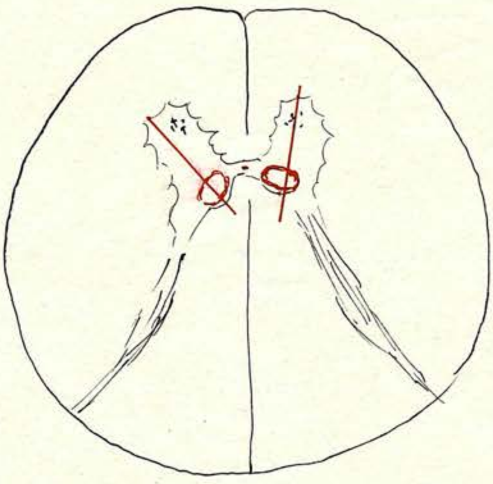


Microcephale.

in the human cord at this level. The cells are becoming more numerous than in the last segment. They are small in size and are all well stained, with central round nuclei and Nissl granules.

The reduction in size of the posterior horns is very marked, the substantia gelatinosa Rolandi being small in amount.

Ninth Dorsal Segment

This segment is also round. The anterior and posterior median fissures are not in the same plane, and the central canal is also pushed towards the lesser side. On the larger side the grey commissure is long and passes gradually into the crescent, while on the smaller side, the grey commissure has been so reduced in size that the column of Clarke is in close relation to the central canal. In the latter case the long axis of Clarke's column is nearly parallel to the posterior median fissure, while in the former it forms an angle of about 150° with the grey commissure. The anterior horns are both displaced obliquely, but are becoming more like the normal appearance found in man. The motor cells are beginning to be divisible into an antero-mesial and a postero-mesial group; but they are small in number and size.

The lateral horn has been displaced very far backwards, being situated behind the level of Clarke's column.

The posterior horns are again small, while the substantia gelatinosa Rolandi is markedly reduced.

Tenth Dorsal Segment

This segment is round. The anterior median fissure is half the length of the posterior median fissure. The central canal is elongated laterally and the anterior and posterior grey commissures are equal in thickness and slightly curved. The anterior horns have approached still nearer to the anterior median fissure, but their inner margins are not yet parallel to it. The motor cells are divided into an antero-mesial and a postero-mesial group, each in its normal position. Clarke's column is in the normal position found in man. The cells are becoming larger and are all well stained and of nearly the same size. The lateral horn is still situated very far back, but the cells of the intermedio-lateral tract stain well and are quite numerous. The posterior horn is markedly reduced in size, especially at the anterior end of the substantia gelatinosa Rolandi. The posterior white columns are well developed and large. The most characteristic feature of the white matter is the large number of fibres in the anterior white column.

Eleventh Dorsal Segment

This section resembles the last very closely. The anterior cornua are longer and approach closer to the median line. The diminution of the posterior horns is very marked. Clarke's column is large and occupies the normal position found in man. The cells are very numerous and stain well. The anterior white columns are still large, but not quite so large as in the last segment.

Twelfth Dorsal Segment

A section at this level differs very little from a normal human cord. The anterior columns are long and well marked. The antero-lateral angle is present. The lateral horns are well marked and the cells of the intermedio-lateral tract are well developed. The posterior horns are again much diminished in size. The position of Clarke's column is interesting, as instead of lying along the inner side of the posterior horn, it is so placed that its long axis is very nearly in the same plane as the grey commissure. It has in fact been rotated round an angle of about 60°, which has been shown by Waldeyer to be the position in which the tract is situated in the gorilla. The cells are very numerous and stain well.

First Lumbar Segment

A section at this level is about circular, tending to project slightly anteriorly. The anterior median fissure is almost as long as the posterior median fissure and is well marked and open. The posterior median fissure is closed. The central canal is elongated laterally and the anterior and posterior grey commissures are of about equal breadth.

(The outermost zone of this segment stains much lighter than the rest, owing to the fixing material evidently being very strong).

The posterior cornua are wide apart, especially at the extremity, showing that we have also present here the same large development of the posterior columns of white matter. The direct cerebellar tract is well developed and closely defined. The pyramidal tract is feebly medullated and small. The tract of Gowers also appears faint and not well differentiated. The direct pyramidal tract does not appear very deeply medullated.

The difference in size of the two halves of the cord is well marked in this segment and on the larger side the antero-lateral basis bundles appear to be developed to a much larger extent than on the smaller side. This unequal development has also caused a pushing of the central canal to one side and thus the crescent on the larger side has a much longer neck than the crescent on the opposite and smaller side. It is also slightly curved. The general form of the grey matter at this level resembles that of the normal cord. The most striking feature is the great development of Clarke's column. It is larger than is usually found, oval, and forms a marked prominence on the posterior white columns. The angle which its long axis makes with the posterior median fissure it larger than that usually found.

The anterior horns are thinner than usual; the inner surface is straight and parallel to the anterior median fissure; the anterior surface is slightly concave and small, and the antero-lateral surface also concave. The posterior angle is well developed. The neck of the posterior horn is narrow, and the shape may quite be described as "lancet-shaped".

(There has been a venous congestion at this level).

Cells :

The antero-mesial group is here represented by from three to six cells, small in size. They stain clearly and show Nissl granules.

The postero-mesial group contains from two to six cells; many are markedly small and in various stages of atrophy.

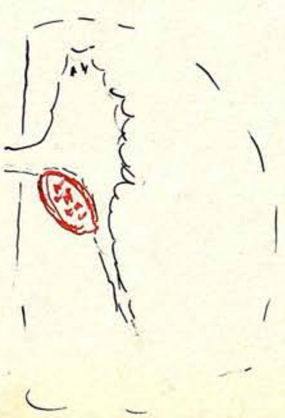
The intermedio-lateral tract is well developed and shows the two groups - "reticular" and "apical" - which we now know is characteristic of this tract at this level.

The cells of Clarke's column are very numerous. They stain rather fainter than the motor cells in the anterior cornu. The general direction of the axis of the cells is parallel to the long axis of the column, which does not differ very much from that found in man. The nucleus of many of the cells is very clearly excentric and all the cells do not show clearly Nissl granules.

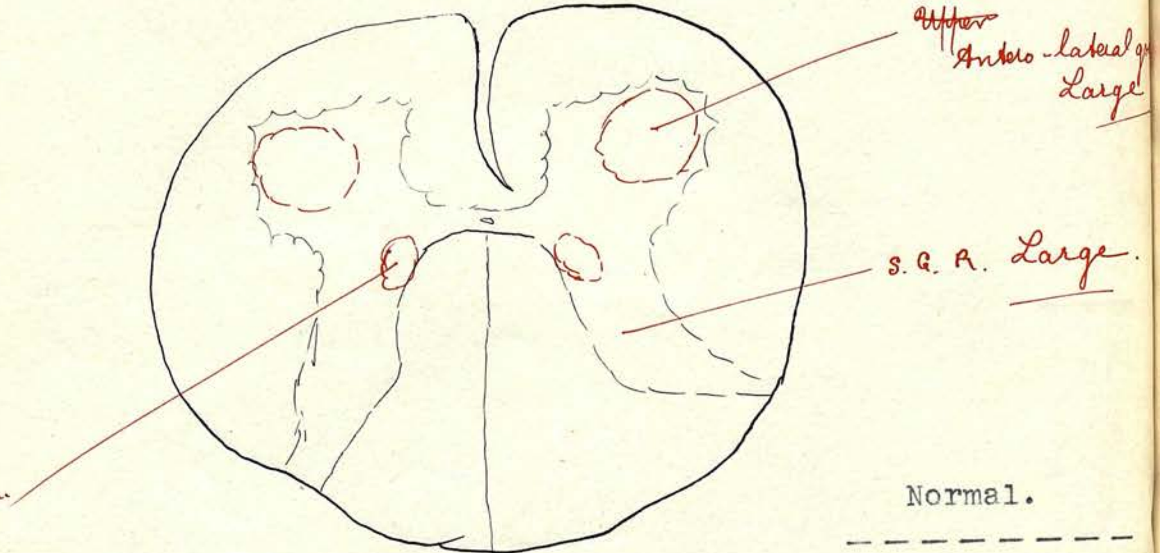
Middle Cells are not strongly developed at this level, although there are many present.

The antero-lateral group just commences here and is represented by from one to five cells.

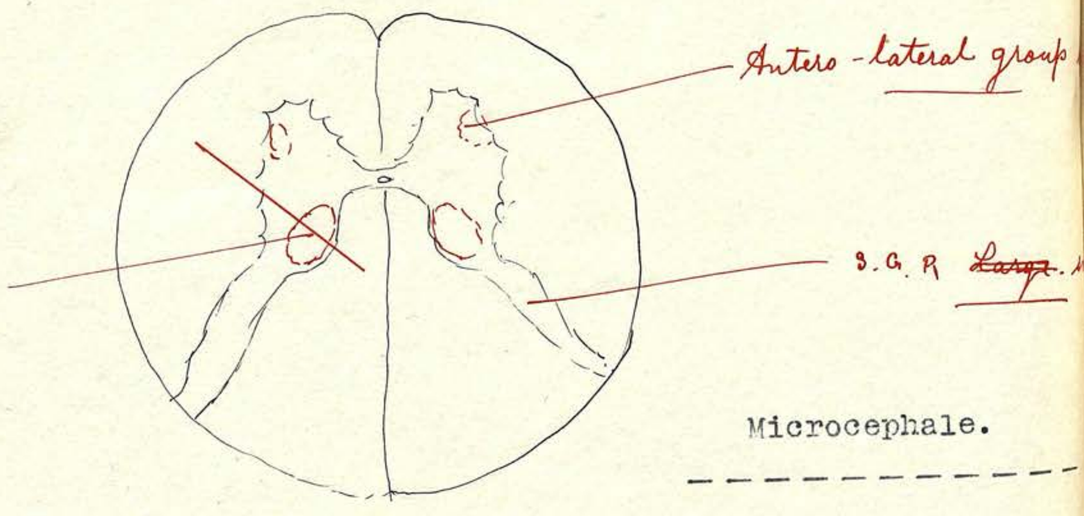
In the upper parts of this level Clarke's column shows an arrangement which I have drawn here.



Second Lumbar segment.



Normal.



Microcephale.

Second Lumbar Segment

This section is almost round, but owing to the slight projection anteriorly, its antero-posterior diameter is slightly the larger. The anterior median fissure is rather shorter than the posterior (as 3:4). The central canal is elongated laterally, and as we found in the last segment, pushed to the smaller side. There appears to be a projection of the grey matter of the posterior white columns at the place of entrance of the posterior roots.

The tracts of the white matter resemble those of the last segment. The direct cerebellar tract is still visible, while the tract of Gowers is not well medullated.

The most characteristic point about this segment is the absence of the antero-lateral horn. It is indicated, certainly, on the larger side, but is completely wanting on the smaller side. The inner surfaces of grey matter pass rather outwards from the anterior median fissure, the antero-mesial angle is rounded, the anterior surface convex outwards and not very broad, the antero-lateral angle also round, and the lateral surface straight. At the postero-lateral angle there is not a distinct lateral horn, although the intermedio-lateral tract is present. The main mass of grey matter is situated in front of the grey commissure.

The column of Clarke is very well marked, although not so large as in the 1st lumbar segment. The long axis makes a larger angle with the posterior median place than does the axis on the narrow side. The neck of the posterior horn is much narrower than normal, and the substantia gelatinosa Rolandi is lancet-shaped.

Cells : The antero-mesial group is represented by from five to seven cells, some of which are of very small size.

The antero-lateral group is represented by several cells, some of which are beginning to atrophy. They show Nissl granules, but their diminution in size is not so great as those we found in the upper cervical antero-lateral group. The intermedio-lateral tract group is only present on the one side, and shows both apical and reticular groups. Clarke's column is very strong in cells, and on the larger side shows very little diminution from the last segment. The majority of the cells are of large size and show the same excentric nucleus and vacuolated appearance we found in the first lumbar region. The Nissl granules are limited to the periphery.

A few small cells near the antero-mesial angle may represent the "anterior" group of cells.

Third Lumbar Segment

A section at this level appears only slightly larger than the last segment. It is also circular. The anterior median fissure is to the posterior median fissure as 3 : 4. The central canal is small and elongated. The anterior and grey commissures are of equal thickness and corved concavely downwards, the greater concavity appearing on the larger side, so that the posterior median fissure becomes bent over to the opposite side. (See fig.)

The posterior columns are still large and well developed, and push the posterior horns further out from the mesial place than is quite normal. The antero-lateral columns are also larger than usual. The direct cerebellar tract is scarcely visible, while the tract of Gowers appears very faint beside it. The pyramidal tract is fully medullated and small.

The most striking peculiarity of this level is the extraordinary small development of the antero-lateral cell group. This group appears usually at L2, where it forms a very prominent angle. At the level of the third lumbar it is very marked, and prominent, (see fig.). The number of cells is normally great, and the postero-lateral and central groups also contain large numbers of cells. These are both very poorly represented here, and thus the amount of grey matter is much reduced, so that the shape is considerably altered. In shape it resembles a second lumbar segment far more than a third. The inner surface passes upwards parallel to the anterior median fissure. The antero-mesial angle is well marked, and the antero-lateral surface passes outwards, forming a convex curve to the base of the horn. The neck of the posterior horn is narrow; the substantia gelatinosa Rolandi, though large, is not so large as is found normally at this level.

White Matter :

The posterior columns are still well represented. The direct cerebellar tract has disappeared. The crossed pyramidal stains feebly. Gowers's tract is still present; it does not stain well

Grey Matter :

The antero-mesial group consists of several small cells. The antero-lateral group is particularly conspicuous by the very few small number of cells it contains, a fact which is all the more remarkable when we remember that it was almost completely absent from the second lumbar segment. The postero-lateral group is also very much diminished, and in fact is almost wanting. The central group is still further reduced, being represented only by a few cells which occupy the position this group usually occupies, and probably belong to it. They are so few in number as to be very easily overlooked altogether. There is a slight indication of a division of the postero-lateral group into two. Besides this extraordinary diminution in the number of the cells. there is also a great reduction in size. There is not a single cell present of normal size, while some of them are extremely small. The great majority are intermediate in size. Besides these we also get cells of larger size, but compressed and resembling those I described and figured in the upper antero-lateral group in the cervical region, but these are not very numerous. Almost all the cells show Nissl granules.

The intermedio-lateral group is represented by a few cells in the lateral position in the upper part of the segment.

The middle cells are not particularly numerous.

Clarke's column is represented by well marked groups, the one on the left or larger side being much better developed than the other. The cells almost all show excentric and flattened nuclei. The Nissl granules are limited to the periphery of the cell.

Fourth Lumbar Segment

Compared with the last segment, the fourth lumbar is narrower antero-laterally and broader from side to side. The two sides do not differ very much from each other. The anterior median fissure is not quite so long as the posterior median fissure. The central canal is elongated antero-posteriorly, and the posterior commissure is slightly broader than the anterior.

The amount of grey matter (as well as the number of nerve cells) is very much reduced at this level, so much so that it is the first thing which attracts the attention. The inner surface does not extend very far upwards, and from the antero-mesial angle to the postero-lateral aspect of the base of the anterior cornua, the grey matter appears as a semi-circle, which does not show any depression on the outer surface, or any marked prolongation outwards at the antero-lateral or postero-lateral angles. It thus resembles what is typically found at this level, only on a much smaller scale. The posterior cornua are also much diminished in size; the neck is smaller and the substantia gelatinosa Rolandi is not so well developed as it usually is at this level.

The posterior columns of white matter are well marked. The pyramidal tract (crossed) is very small; the anterior basis bundle is larger than usual. The tract of Gowers seems still present and ~~nearly~~ well medullated.

The grey matter is very much reduced in amount, both in the anterior and in the posterior cornua, and associated with this there is also a great reduction in the number of nerve cells.

This reduction seems to affect both the antero-lateral group and the postero-lateral more than the central group, but in all these groups less than one-third of the normal number of cells is to be found.

Fifth Lumbar Segment

Normally at this level we find the antero-lateral and postero-lateral groups of cells are well and separately developed, forming marked antero-lateral and postero-lateral angles, the postero-lateral angle being at the level of the central canal. The central group of cells is also well developed at this level.

In this microcephale the segment is circular, the antero-lateral fissure being to the postero-lateral as 3.5 : 4.5. The central canal is round. The anterior and posterior grey commissures are about equal in thickness. The one side is still rather larger than the other. The posterior white columns are strongly developed and appear to push the commissures upwards. The crossed pyramidal tract is very poorly represented. The anterior column of white matter appears to be larger than usual. The grey matter is situated mostly behind the level of the commissure. The antero-lateral group is anterior to the place of the commissure, while the postero-lateral group is posterior to it. There is no well marked hollow between these two groups. The base of the anterior and posterior horns are both narrow. The substantia gelatinosa Rolandi is poorly developed. The most marked feature of the grey matter is the very small number of nerve cells present and their small size; and associated with this is the poor development of the grey matter. The antero-mesial group appears in some sections as a few small, faintly-staining cells. The antero-lateral group is well marked off from the central and postero-lateral. It is specially characterised by the few cells present. In some sections it is represented by only one or two cells, the postero-lateral in some cases showing only one cell, and the central three. Besides the diminution in number, the few cells present are very much reduced in size, especially in the postero-lateral group. Such cells are very poor in cell-processes. Nissl granules are usually present, but in some stain very feebly. Some are peculiarly flattened and resemble those previously described in the upper antero-lateral cell group in the cervical region. There is an excess of neuroglia. Of the three groups, the central seems to have suffered least reduction in the number of its cells. In the normal cord there is a tendency for the postero-lateral group to be broken up into subsidiary groups of cells. This is very well shown in this cord, especially as where we find in the normal cord this grouping, here we find instead only a few cells surrounded by a space empty of cells, and in places these groups seem to have dropped out altogether.

First Sacral Segment

Normally the chief difference between this segment and the fifth lumbar is in the greater development and closer approximation of the antero-lateral and postero-lateral projections.

In outline this segment is nearly circular. The anterior median fissure is to the posterior median fissure as 4:5. The

Second Sacral Segment

This section is markedly smaller than the last level. The anterior median fissure is to the posterior median fissure as 4:5. The anterior and posterior grey commissures are not markedly thick and are equal. The section is specially characterised by the great development of the white antero-lateral columns, as we found to be also the case at the first sacral level. The posterior columns are well developed. The pyramidal tracts are markedly small and feebly medullated. Owing to the better development of the anterior columns, the shape of this section bears a strong resemblance to the normal. The antero-lateral and postero-lateral groups are strongly developed, and the cells, although still relatively few in number, are more numerous than in the last segment.

The central group is still present, but the cells are very few in number. The postero-lateral group is very clearly divided into an inner larger and an outer smaller group. It is interesting to note that the outer group is much more reduced than the inner one. The post-postero-lateral group is not well developed in the upper part of this segment, but as we pass down it increases in size, while the antero-lateral and postero-lateral groups diminish rapidly.

The intermedio-lateral tract is not marked.

The substantia gelatinosa Rolandi is reduced in amount and the posterior horns are small.

Third Sacral Segment

This section is much smaller than the last segment. The antero-lateral white columns are still unusually large. The anterior median fissure is to the posterior median fissure as 5 : 6. The posterior grey commissure is thrice as thick as the anterior grey commissure. The form of the grey matter is normal. In the place of the central group of cells there is a second group of small cells present, which are also found in the normal cord. They do not seem to have been reduced to the same extent as the other motor groups. The post-postero-lateral group is also reduced in size and number of cells.

The substantic gelatinosa Rolandi is still small in size.

A very marked difference is seen between the cross section of the anterior and posterior roots at this level, the posterior root containing quite twice as many fibres as the anterior.

Fourth Sacral Segment

The antero-mesial group of cells have reappeared, but are few in number. Otherwise no motor cells are present. There is still an unusually large development of the antero-lateral part of the white matter.

The substantia gelatinosa Rolandi is small in amount.

The posterior horn cells are still darkly stained, the rest of the cord being much more feebly medullated, with the exception of the part of the anterior basis bundle situated between the two anterior horns.

Fifth Sacral Segment

No motor cells are seen here, but the difference in degree of medullation is very clearly visible, showing that it extends right through the cord from end to end.

Summary

The Spinal Cord of the microcephalic idiot is reduced in size, both as regards length and breadth. As the cord had already been divided into segments before it came into my hands, I am unable to state its actual length and to determine if the reduction was proportionate to the reduction in the size of the brain.

The large size of the cervical enlargement is characteristic of the microcephalic cord, being proportionally greater than that found in the normal cord. It is not, however, due so much to an actual increase in the size of the cervical enlargement as to a decrease in the size of the lumbar enlargement.

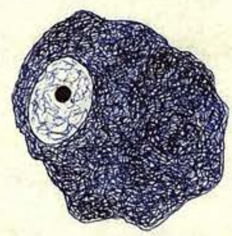
The White Matter

I have shown that the white matter does not stain equally by the Weigert Pal method, some parts staining more deeply than others. Two tracts, in particular, stand out pre-eminently on account of their dark staining; namely,- the tract of the posterior columns and the direct cerebellar tract. I shall consider the former of these two tracts first. If the posterior columns are examined in a section in the lumbar region, stained by the Weigert-Pal method, it will be noticed that the outer and inner fibres stain to an equal degree. The posterior columns present a more or less even degree of staining under the low power, i.e., the fibres are all, as far as it is possible to detect by this method, equally medullated. If, however, a similar section is examined in the cervical region, it will at once be noted that the appearance is quite different. The fibres do not all stain to an equal degree. The inner fibres, i.e., the column of Goll, stain much lighter than the outer column of Burdach. This is specially well seen on examination by a low power. And if the intervening segments of the cord are systematically examined from below upwards, it is found that there is a gradual diminution in the medullation of those fibres which ultimately come to lie in the inner part of the posterior columns, to which we apply the name of the column of Goll. The great difference which exists between the column of Goll and the column of Burdach lies in the fact that the inner fibres have arisen from the lower part of the cord and therefore have a longer distance to travel to reach the medulla oblongata, and as these fibres diminish in size the further they are distant from their origin, the column of Goll consequently consists of smaller fibres than the column of Burdach. But if we examine sections of a normal cord stained in a similar manner, we find that the column of Goll and the column of Burdach stain equally well, and it will be at once apparent that no mere difference in the size of the individual fibres is sufficient to show any great difference in the appearance of Weigert-Pal sections. The feeble staining of the inner fibres in the microcephalic cord, therefore, is not due to any difference in the size of the fibres; it is due to a deficiency in the medullation. It has been shown by Bechterew that the column of Goll and the column of Burdach medullate at different dates. He states "that between the fifth and sixth months of foetal life, a condition is found where the column of Goll is not medullated, while the column of Burdach is, and that, at the beginning of the seventh month, the column of Goll becomes medullated". These two columns, however, have no essential difference from each other. They both consist of fibres arising in the posterior root ganglia and terminating in the gracile and cuneate nuclei. The only difference between them is that the inner fibres, arising from cells in the lower part of the cord, have a longer distance to travel than fibres arising from the upper levels of the cord. The difference in the date of the medullation of the columns of Goll and Burdach, as described by Bechterew - and I have myself confirmed his results - is as follows :- When a nerve fibre medullates, the medullation first commences close to the cell and gradually passes along the fibre, i.e., the distal part of the fibre is later in medullating than the proximal part. When a cell demedullates, the medullation is first lost in the distal part of the fibre and passes along to the proximal part, (Schiefferdecker,(Amyotrophic Lateral Sclerosis)); and now we know that when a fibre remedullates, it is first central also (Cajal, etc.) The reason of the later medullation of the column of Goll is the fact that the medullation which commences in all the posterior root fibres at the same time requires a longer time to reach the cervical region in those fibres which have a long distance to travel than in those fibres which have only a short distance, and thus in a section in the cervical region of a foetal cord, the fibres in the column of

Goll have not medullated at the same time as those in the column of Burdach simply because the medullation in the longer fibres has not had sufficient time to reach the cervical region. The lumbar region in such a cord shows the whole of the posterior columns fully medullated. Now, in the cord of the microcephalic idiot, the inner column (of Goll) stains less deeply with the Weigert-Pal method than the outer column (of Burdach); i.e., it is less fully medullated. This is best seen on examination with a low power. The column of Goll is not non-medullated; it is medullated, but the degree of medullation is less than that in the column of Burdach; i.e., the cells from which these fibres arise have not been able to completely medullate the more distal part of the fibres. (I do not propose to discuss from whence this medullated sheath arises, whether it is a secretion of the axis-cylinder, or a chemical action with surrounding tissues, or a secretion from the cells of Schwann, which in the central nervous system later disappear.) We know that in pathological conditions, e.g., amyotrophic lateral sclerosis and other toxic diseases of the nerve-cell, the medullation of the fibre disappears, and in amyotrophic lateral sclerosis, where, as far as our knowledge goes at present, there is a primary lesion in the nerve cell of the motor cortex (and perhaps also in the spinal cord), the pyramidal tract first begins to show a sclerosis in the lumbar region only, while in more advanced cases the pyramidal tract may be unstained by the Weigert-Pal method as far up as the decussation of the pyramids, and in still more advanced cases as far as the crura cerebri, i.e., the fibres have lost their medullation from the peripheral part first, and this has gradually travelled up the fibres to the central part. From whatever source it will ultimately be shown that this medullated sheath is derived, we can certainly say that when the cell is affected primarily the medullated sheath disappears, and if the activity of the cell is affected so that it is unable to discharge its full function, it will be the more distal part of the fibre which will be affected, the proximal part being, as far as it is possible to tell, fully medullated. This is what has occurred in the microcephalic cord; the cells of the lower posterior root ganglia have been unable to medullate fully the whole length of the fibres arising from them, and in consequence when we examine the columns of Goll and Burdach in the cervical region, we find the fibres composing the column of Goll less fully medullated than those composing the column of Burdach. Why this should be so in the microcephalic cord is a point which I propose to discuss fully after I have first described the other appearances of the cord. (The posterior root ganglia were not removed, and thus I am unable to state what was the condition of the cells in them.)

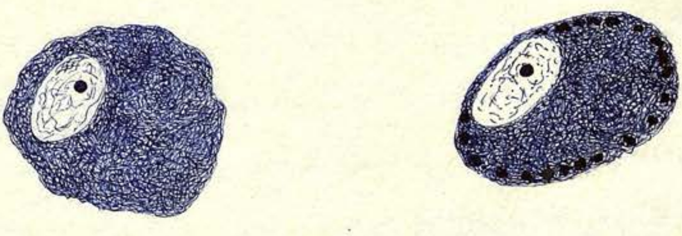
The second tract which stands out prominently in the microcephalic cord is the <u>Direct Cerebellar Tract</u>. This tract is well medullated, and its fibres are strong, large and well stained.

It is a tract which is very well developed in the higher apes, forming a special projection on the lateral part of the medulla oblongata, before it ultimately passes into and becomes lost in the restiform body. It is a tract which medullates early. I have found it darkly stained in Weigert-Pal sections in a five month human foetus, and it appears to medullate very shortly after the posterior columns, which are the first fibres to medullate in the foetal cord. The direct cerebellar tract arises from the cells of Clarke's column (Mott, etc.). And now I propose to study the cells of Clarke's column in the microcephalic cord very fully, as they exhibit some very important points. I do not at this stage propose to discuss the position of the axis of the column of Clarke in relation to the rest of the grey matter; this I shall consider in full, later. At this stage I am only concerned with the character of the nerve cells themselves which are situated in this column. The cells show the usual characteristics of the cells in Clarke's column, and are all well-marked and full of Nissl granules, as we should expect considering the strong medullation of the direct cerebellar tract. This statement, however, requires certain qualifications. The column of Clarke stretches from the fourth cervical segment to the middle (or lower part) of the second lumbar segment; i.e., cells are found in the position of Clarke's column for this extent. From the upper part of the fifth cervical segment to the lower part of the eighth cervical segment, the cells in this position are few in number. In the human cord there are rarely more than three cells to be found in any one section, and if the cervical region is examined in serial sections, which I have done, it will be found that it is only in every tenth or twelfth section that any cells are present in this position. These cells form the "cervical nucleus of Stilling". They are large cells and measure three or four times greater in diameter than the cells in the upper part of Clarke's column proper (i.e. "the dorsal nucleus of Stilling") which begins at the first dorsal segment. But these cells in the "cervical nucleus of Stilling" show a most important and significant condition; they are not normal. They show no Nissl granules and the nucleus is pushed to one side of the cell and flattened out. The nucleolus stains well. The protoplasm does not show the homogenous hyaline appearance which is characteristic of degenerated nerve cells; it shows instead a deposit scattered all through it of some very fine granular matter. I have attempted to illustrate this condition in the accompanying figure.



It is not a condition which is only found in a few cells in the "cervical nucleus"; it is found in them all. It is not a condition compatible with the full activity of the cell, but on the other hand it is not a condition of degeneration ; it is a condition of diminished activity - a condition in which the cell is discharging its function continually, but not to the full amount. It is a condition which is also found in the cells at the lowest extremity of Clarke's column and therefore I shall leave the discussion of its significance till I have described these. The cells of Clarke's column proper, which begin at the lower part of the first dorsal segment and extend to the middle or lower limit of the second lumbar segment (more rarely the beginning of the third lumbar) are very different from those which I have just described. They are in every way most typical normal cells. They contain a central nucleus and large, well-formed Nissl granules staining sharply. In a certain number of these cells the Nissl granules have a tendency to stain faintly or even not at all; in some cells some of the granules stain well and others have apparently dropped out (see Figure). But these changes are of no significance; they are just the changes which are to be found from purely post-mortem changes. (In this case there was a period of nearly forty-eight hours before the post-mortem was made). And although some of the cells show alteration in the Nissl granules, they all show a central nucleus, rounded in outline, with a well marked-nucleolus.

When we come to examine the lower cells of Clarke's column, it will at once be noted that a great change has taken place again in the character of the cells. They are large round cells, with a flattened eccentric nucleus situated at the periphery of the cell and in most cases causing the wall to bulge. In some cases the nucleus appears half in the cell and half out of it, presenting a peculiar appearance. The body of the cell stains lightly ; there are no Nissl granules present in the centre of the cell, which presents an even granular surface. In some cells there is absolutely no trace of any Nissl granules. In others there are Nissl granules which are arranged round the periphery of the cell as I have depicted in the accompanying figure. These granules are small in size and do not stain well. The cells have the appearance as if Nissl granules had never been formed in them. They are exactly similar to those cells which I have described in the "cervical nucleus of Stilling". They are cells which are not in a state of full activity and yet are neither degenerated nor atrophied. They are in a state of only partial activity and form a most striking feature of the



cord, especially when contrasted with the cells in the upper part of Clarke's column. These two, however, pass into each other gradually. The normal cells extend from the first dorsal segment to the middle of the first lumbar segment, and the other type of cell is found in the first and second lumbar segment. The transition of the one type into the other is gradual ; i.e., in a section at the middle of the first lumbar segment we find both types of cells lying side by side. We do not, however, find cells intermediate in character between the two above types; we simply find the two types of cell mixed with each other at the line of demarcation, so that the two types are not separated from each other by a sharp line. For convenience I shall call the normal cells the "upper group" and the abnormal cells the "lower group". We know, beyond all doubt, that the cells of the "upper group" send their axons into the direct cerebellar tract. This tract is well marked and fully medullated, and thus we should expect to find that the cells from which it arises are normal. It is generally held that the whole of the cells of Clarke's column send their axons into the direct cerebellar tract. But it is quite incompatible that a direct cerebellar tract so completely medullated as in this case could arise from cells showing the characters which I have just described for its "lower group". There are not even any poorly medullated fibres in the direct cerebellar tract which might arise from such cells, and we therefore can only come to the conclusion that the direct cerebellar tract arises from these cells which are normal (i.e. from the first dorsal to the first lumbar), and from these cells only, and that the axons of those cells which arise from the "lower group" must pass elsewhere. The probable explanation is that this lower group sends its axons into the tract of Gowers. The origin of this tract is unknown, and is generally stated as being from "cells in the posterior horn", but the exact localisation of such cells has never been demonstrated. The tract of Gowers medullates later than the direct cerebellar tract, to which it bears a relation somewhat similar to that borne by the column of Goll to the column of Burdach - namely : they both have the same termination, and if this hypothesis be true, the same origin. Their course is different and chiefly affects them in their relation to each other, to the extent that the fibres of the tract of Gowers arising lower down and having to pass up to the superior cerebellar peduncle are necessarily much longer. As regards their time of medullation, they medullate shortly after the direct cerebellar tract. Probably, as in the column of Goll, this is due to the fact that the medullation has not yet passed up to the upper part of the cord so soon as in the direct cerebellar tract where the distance is shorter. As, however, the fibres of the tract of Gowers are intimately mixed with the descending fibres of Lowenthal, the anterior basis bundle fibres, and fibres from the cord passing higher up than the cerebellum, it is very difficult, in fact almost impossible, to state whether the fibres of the tract of Gowers are fully medullated or not, since we cannot say for certain whether any one particular fibre belongs to this tract or not. But when we examine a section of the cervical region stained by the Weigert-Pal method, we are at once struck by the faint staining of the antero-lateral portion of the white matter, showing almost all the fibres in this part of the cord are poorly medullated, and therefore amongst them those of the tract of Gowers. (For a complete description of the fibres in this region of the cord, see below). The argument is thus as follows :- the direct cerebellar tract is completely medullated; the cells of Clarke's column from the first dorsal to the upper part of the first lumbar are typical normal cells (except for some slight post-mortem changes). The cells below this level (i.e. in the first and second lumbar segments) are abnormal and appear to be in a state of diminished activity, and this is associated with a feebly medullated tract of Gowers; and lastly the cells of the "cervical nucleus of Stilling" also show this abnormal character and therefore cannot give rise to fibres passing into the direct cerebellar tract. Where these fibres go is as yet undecided. "The sacral nucleus of Stilling" I have been unable to find. (It is usually stated that Gowers' tract arises from "cells in the posterior horn". Curiously in this cord the cells in the posterior horn stained usually distinctly and were all normal).

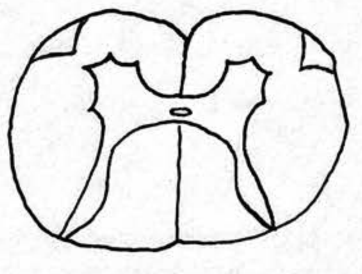
I pointed out that there is a very great difference in size between the normal and the abnormal cells of Clarke's column in the cord. As we trace the size of the cells of Clarke's column from above downwards, there is a gradual increase in the size of the cells, but when we reach the abnormal cells there is a sudden increase which is quite out of proportion to the gradual increase which has occurred up till now. As this may be due to a simple swelling of these cells, I have examined a normal cord and measured the size of the cells of Clarke's column at the different levels and can state that there is a <u>sudden</u> increase in the size of the cells at the level of the first lumbar segment, an increase which is quite consistent with the view that the size of a cell and the length of its fibres bear a definite relation to each other, the longer fibres arising from the larger cell, the sudden increase in size here corresponding to the increased length of the fibres of the tract of Gowers compared with those of the direct cerebellar tract. There are many other points in favour of this view which I do not propose to discuss here, as I am already engaged in determining this question from the experimental side.

The remaining tracts in the cord are all poorly medullated and may be divided into two groups : first those with only a feeble amount of myeline, and second those without any, this latter group consisting of the tract of Helweg. All the motor tracts are poorly medullated. The crossed pyramidal tract is small in size, (best seen in the medulla), the fibres are poorly developed and stain faintly by the Weigert-Pal method. There is an increase of neuroglia between the individual fibres. As these fibres are traced from above downwards, they also show the same gradual diminution in the amount of myelin similar to that in the column of Goll, only in this case as we are dealing with a descending tract, it is in the lower levels of the cord that this diminution is most marked. In the upper cervical region the crossed pyramidal tract stains darkly; in the lower dorsal and upper lumbar region it stains feebly and the amount of neuroglia between the fibres is increased, but even in the upper cervical region the fibres are not completely medullated and stain distinctly feebler than the direct cerebellar tract fibres. This condition is important in connection with the motor nerve cells in the anterior cornua. They are greatly reduced in number in the cervical region, but far greater in the lumbar region, and this is probably due to the diminished amount of myelin in the lower part of the pyramidal tract, which interferes with the complete continuity of the motor arc.

The antero-lateral descending fibres of Löwenthal are also not fully medullated. As they are mixed with the ascending fibres of Gowers' tract, it is not easy to determine which fibres belong to which tract, but from the general want of medullation in this region, it is quite possible to state that the fibres of both tracts are considerably affected.

The rubro-spinal tract (pre-pyramidal) is also not completely medullated.

The tract of Helweg is a small descending tract, triangular in area, found in the antero-lateral part of the cord in the cervical region. It arises somewhere in the neighbourhood of the olive and terminates about the fifth cervical segment. In the microcephalic cord it stands out prominently since at the fourth to fifth



cervical segments it is completely non-medullated. As it is traced up towards the olive the proximal part of the fibres becomes faintly medullated, and still higher up in the medulla the fibres are still better medullated ; so that here again we have the same condition, namely, the medullation falls off gradually as we pass away from the cell. If the tract of Helweg is examined in a normal adult human cord, it is usually found to stand out somewhat prominently at the fourth and fifth cervical segments owing to its lighter colour. There is a description of this last tract by Giannelli (Journal of Mental Pathology, Vol. viii, No. 1, p. 1.) who examined it in an idiot ~~infant~~ cord and traced it up above the inferior olive (since it was also extremely faintly medullated), and he states there that the fibres come to surround the olive so that he calls it a "circumolivary tract", and thinks it arises from the "dorsal leaflet of the inferior olive". In this case the cells in the inferior olive all stained well and were normal, and thus it does not appear that it can arise from the inferior olive. Above this level there are many groups of abnormal cells, but owing to other changes which I shall describe later, it is not possible to draw any definite conclusion about the origin of this tract from this cord.

The order of medullation of the tracts in the foetal cord is as follows :-

Tract of the posterior columns	3rd and 4th months
Direct cerebellar tract	" " " "
Gowers' tract	6th month
Pyramidal tracts	Shortly after birth;
Tract of Helweg	Usually never completely

In the microcephalic cord an arrangement analogous to this is present. The first two tracts are fully medullated, the next two are poorly medullated, and the last is scarcely medullated at all. The condition here is one of defective medullation, the later the tract medullates the greater being the want of medullation. Some interference with the normal process of development has occurred, which has prevented the complete medullation of the various tracts. It is a cause which has not affected the first two tracts, some they are fully myelinated. It has come into action about the third month (as I shall discuss in detail later) and thus those tracts which are already myelinated have not been affected, while those which medullate later are affected in such a manner that the cells from which they arise have their energy so diminished that they are unable to completely medullate the whole length of their axons. The condition here is the result of the same cause as has produced the changes which I have just described in the brain.

I have pointed out that a complete explanation of all the changes which occur in the microcephalic brain may be found if we regard the condition as the result of the superposition and subsequent development of a smaller and simpler type of brain upon an already normal sized, three months' brain. The change has also affected the spinal cord in a similar manner, and as a result the nerve-cells there have been suddenly affected so that instead of continuing their normal course of development towards the complete full-sized condition, they have proceeded along this reduced line of development towards the smaller type, and thus have only been able to medullate their axons in proportion to the reduced function which is required for the reduced type. And since the fibres have already been formed before this change has occurred, the result is that the diminished functional activity of the cells is only sufficient to medullate that part of the fibre corresponding to the length of the fibres in the superposed, reduced condition (which is shorter than the normal length), and thus that part which is of the same length as the superposed length will be fully medullated and that part which is in excess will be unmedullated. We do not, however, actually find such a sudden and sharp transition between the medullated and unmedullated part of the fibre. There is instead a <u>gradual</u> loss of myelin as we pass along the fibre towards the distal end, the sum total corresponding to the amount of energy which the cell is capable of producing as the result of this peculiar change which it has undergone. Those tracts, the upper posterior columns and direct cerebellar tract (posterior longitudinal fasciculus, cranial nerve fibres, etc.), which have already medullated before this change has occurred, are unaffected. (I shall return to this question later).

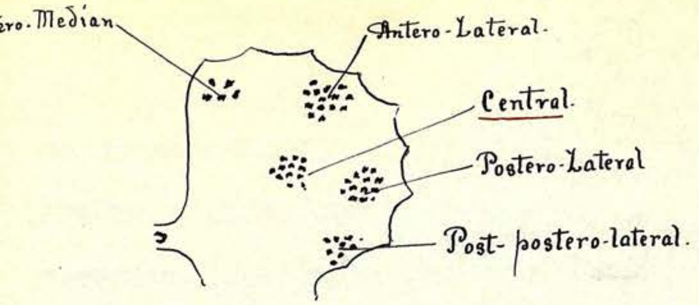
Grey Matter

The study of the grey matter in the microcephalic cord is of very great importance and significance owing to the very remarkable changes which have taken place. "The reduction in size of the cord is entirely secondary to the condition of the brain", but I shall also wish to determine whether the spinal cord is not primarily affected over and above this, and the most important evidence in favour of this last consideration is found in the grey matter.

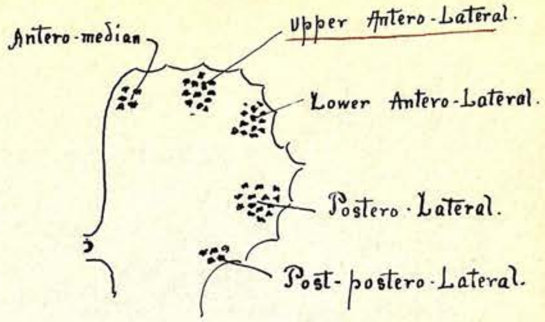
Motor Cells in the Spinal Cord

The motor cells in the anterior cornua are greatly diminished both in size and in number. This diminution is most marked in the cervical and lumbar enlargements, the greatest deficiency occurring in the lumbar region. In the lumbar region the small number of cells can only be described as extraordinary; e.g., the postero-lateral group of cells which normally may contain as many as fifty in one section has been reduced in the microcephale to fifteen. The reduction in the number of cells in the cervical region is not so marked ; e.g., the postero-lateral group, which is normally represented by about thirty-five cells in one section has been reduced to from twelve to eighteen, thus showing that the reduction in the number of cells is not so great as in the lumbar region. (I have given a complete list of the number and size of the cells in all the groups at the end of this paper). I have already pointed out that the pyramidal tracts stain more and more faintly by the Weigert-Pal method as they are traced down the cord, showing that the medullation diminishes gradually towards the more distal part of the fibres ; and here we find the explanation probably for the greater reduction in the number of anterior horn cells in the lumbar region compared with the cervical region, at which level the pyramidal tract is far better medullated. The diminution in the number of motor cells in the cord is thus secondary to the reduction in the motor area which has occurred in the brain (as I have already described), and the deficient medullation in the distal part of the pyramidal tract fibres is quite a sufficient explanation of the greater reduction in the number of cells in the lumbar region. The motor cells are reduced in size and are rather poor in processes. There is an excess of neuroglia throughout all the cord. The most characteristic feature of these cells, however, is their normal appearance. They stain very well with methylene blue stains, the Nissl granules in particular standing out clearly and staining well. There are very few motor cells showing degenerative changes, and although they show all gradations in size, the nucleus stands out clearly, stains well, and is situated in the centre of the cell, so that the very smallest cells just appear like miniature large ones.

There is one particular group of cells in the cervical region which differ from those which I have just described, and which I shall now discuss in detail. The grouping of the nerve cells in the lumbar enlargement has been very fully described by Van Gehuchten and later by Sano, who divide them into four groups, an antero-lateral, a postero-lateral, a post-postero-lateral and a central group.

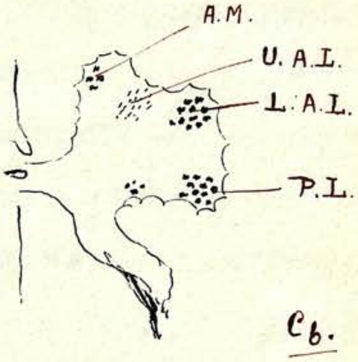


Lumbar.



Cervical.

The arrangement of the groups in the cervical enlargement has not yet been so carefully marked out, but the groups which are present are not directly comparable ; there is a post-postero-lateral group, a postero-lateral group and an antero-lateral group, which at the level of the fifth cervical segment is divided into two groups. Some observers hold that of these two groups one represents the antero-lateral group proper, and the other corresponds to the central group in the lumbar region. Sano, Van Gehuchten, Bruce and others, however, hold that there is no representative of the central group in the cervical region, and that both those groups are antero-lateral groups ; i.e., the group in the cervical region corresponding to the antero-lateral group in the lumbar region is double ; it consists of an upper and a lower group, the upper group appearing in the fourth and fifth cervical segment, the lower in the fifth and sixth segment, and thus the two groups overlap at the fifth segment and both appear in the same section. That this latter view is the correct one is most strikingly demonstrated by the microcephalic cord. If a section at the level of the fifth cervical segment be examined with a low power, it will be noticed that while the lower antero-lateral group stands out clearly, the upper antero-lateral group appears to be absent, or rather its place is taken by a number of small rods (see figure). If these rods are examined under a high power, they will at once be recognised as atrophied nerve cells.



They show no degenerative changes whatever. The cell is elongated and small, the nucleus lies in the centre; there is extremely little cell body, the protoplasm is very scanty and the Nissl granules are present. The appearance is best seen from the following figure. The cells represent an extreme condition of atrophy, they are not degenerated; there is no extension of the nucleus or loss of Nissl granules or hyaline appearance of the protoplasm, and an atrophy of this kind has never before been demonstrated.

It is a "<u>selective muscular atrophy</u>"; it is entirely limited to one particular group of cells which show an extreme degree of the condition, while none of the surrounding cells show any signs of a progressive change. The cells have obviously not completely lost their function, as although they are so altered, they retain their Nissl granules. The explanation of this condition forms one of the most interesting and important points in connection with microcephaly. In the lower ape there is only present one antero-lateral group in the cervical region, and that is the lower. The upper antero-lateral group of man is absent in the lower apes. As far as I can determine, both groups are present in the cord of the gorilla (Waldeyer), but this point is not emphasised in his paper, and it is not clear from his figures, but as far as it is possible to judge, both groups are present. It is thus clear that the presence of this upper antero-lateral group in man is an advance on the lower ape. I have pointed out that all the features of the microcephalic brain may be completely explained by an interruption of development and subsequent superposition of a small sized ape-like brain upon an already normally developed three or four months' foetal brain, and I have also shown that a similar change has occurred in the cord at the same time (as shown by the white matter). If the spinal cord have developed normally as far as the fourth month, this group of cells would be formed (Bechterew), but if now the development be interrupted and an ape-like condition superposed, i.e., a condition in which this group of nerve cells is unrepresented, the necessary result will be a simple atrophy of this group, which is exactly the condition which has occurred here, and this forms a most beautiful and convincing proof in support of this view.

The cells of the intermedio-lateral tract stained normally.

The "middle cells of Waldeyer" are increased in amount, especially in the cervical and lumbar enlargements.

Is there a Micromyely ?

The question as to whether there is a primary change in the cord is one of very great importance, since if so, we make another advance in our knowledge on this subject, as we are at once in a position to exclude any theory of this condition which only accounts for the smallness of the head or of the brain and assumes that all other changes are secondary to the primary change in the brain and skull.

The spinal cord is undoubtedly greatly reduced in bulk, as might be expected. The greatly diminished motor area must necessarily give rise to a small pyramidal tract and the same may be said of all strands which connect the cerebrum and cerebellum with the spinal cord.

Steinlechner-Gretschischnikoff in 1886 described the changes in a microcephalic cord and came to the conclusion that the changes in the cord are purely secondary to, and dependent upon changes in the brain. Theile, Hervouet and Kassowitsch support these conclusions.

Giacomini has studied this question very fully and he attaches very great importance to the changes which are found in the cord, and insists that the spinal cord is, to some extent, primarily affected in its various segments. He states as follows :- "In the spinal cord we have a double cause which leads to its diminution ; a primary cause which acts directly upon the development of its segmental part, and it is this which first manifests itself; another secondary which appears later, and affects the paths which bind the spinal centres to the brain-centres, and chiefly the long cerebral path. The segmental part, being more intimately connected with the periphery or the motor and sensitive field, shows a development almost normal ; it participates in a less degree in microcephaly ; the cerebral path, on the contrary, which is in relation with psychical manifestations, would have a more important part".

Cunningham (p.338) has "carefully studied the evidence which Giacomini has adduced in support of the statement that the spinal cord is primarily and individually affected outside its brain connections, and is of opinion that it cannot by any means be considered to be conclusive. It is a question which can only be finally decided by further and more extensive research".

Mingazzini (Monatsschr. f. Psychiat. u. Neurol., 1900, p.429) describes very fully a microcephalic brain, both macroscopically and microscopically, and also gives an account of the changes found in sections of the medulla and the spinal cord. He points out a number of changes which he found to be present, and concludes that no primary changes are to be found in the microcephalic cord to which any great importance can be attached.

There have been numerous other smaller and isolated observations on the spinal cord of microcephalic idiots, which I have abstracted at the end of this paper, none of which, however, have produced any results of great value.

In the cord of Robert Lindsay I have already shown that there is a reduction in the size of, and an absence of medullation in various descending tracts, a change which is clearly secondary to the condition in the brain. But there are also similar changes in the ascending tracts, changes which are not sceondary to changes in the brain, and which are necessarily of a primary nature. But the greatest change of all is to be found in the grey matter, which in the dorsal region has undergone an alteration and modification so remarkable that I shall discuss it in full detail. It is a change which is limited mostly to the dorsal region of the cord. If it were purely secondary to the cerebral condition it would affect the whole length of the cord. It is a change which can only be due to some primary cause acting directly upon its development, and can best be understood from a study of the foetal and ape cords.

Comparison of the Spinal Cord of the microcephalic idiot, with that of the anthropoid and lower apes.

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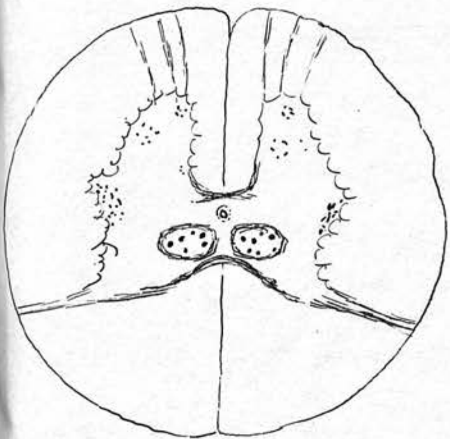
Waldeyer, in his monograph on the spinal cord of the gorilla has shown that the principal difference between the spinal cord of the gorilla and of man is to be found in the dorsal region, and consists in;-

I. A nearly equal depth of the antero-mesial and postero-mesial furrows;

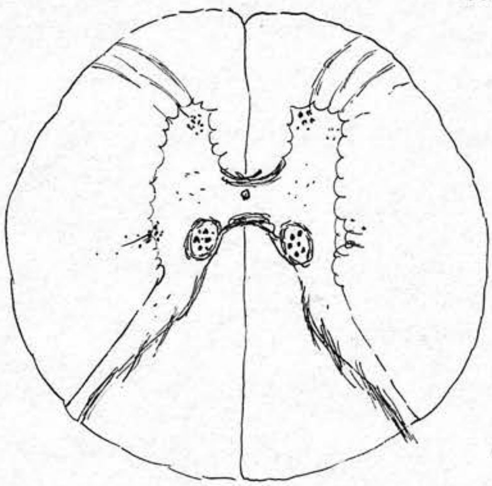
2. A great shortening of the posterior horn of grey matter, which consequently falls far short of the surface of the cord.

3. The form which is assumed, and the position which is occupied by Clarke's Column. In man this group as seen in transverse sections, presents a sagitally oval form, and is placed well behind the central canal of the cord; in the gorilla it assumes a transversely oval outline and lies close up to the central canal.

Gorilla.



Man.

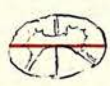


Giacomini gives figures of sections through the dorsal regions of three microcephales. The figures are very small(less than an inch each) but in two cases little or no resemblance is shown to the cord of the gorilla. The postero-mesial furrow is twice as long as the anterior mesial furrow, and Clarke's Column pre presents the usual human form and position. In the third case the condition is altered somewhat. The two mesial furrows are represented by Giacomini as being of nearly equal depth, Clarke's Column lies far forward and the long axis of the cell group as seen in transverse section is oblique and not sagittal in its direction.

At first sight the resemblance between the cord of the gorilla and that of the microcephale appears to be very slight, but this is not really so, and we shall follow out the various points very closely;-

<u>I. The large size of the cervical enlargement.</u>
The cervical swelling is unusually large in the gibbon, and is associated with the long arms which this ape posseses, since it is able to touch the ground with its fingers while standing upright. In the chimpanzee, and still more marked in the orang, the size of the cervical enlargement is quite out of proportion to what would be expected from a comparison with the size of the arms. In the microcephale, we find that there is a disproportionately large cervical swelling, and the resemblance is interesting.

<u>2. The round character of the cord in transverse section.</u>
This, of itself is of very little value, but associated with other points is worthy of note. In man, it is usual to find the cord in the cervical region of an oval shape, while in the gorilla (as figured by Waldeyer) and in the gibbon and orang, the outline is round. There is however, a type of cord found quite normally of a roundish outline, but the condition, in this case, is interesting.



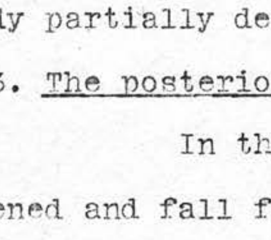
<u>Ape</u> <u>Man</u>

We have seen that the principal difference between the cord of a gorilla and man, is to be found in the dorsal region; and one is at once struck by the fact that it is in the dorsal region of this cord that the peculiar changes (which have been already ~~been~~ described) are found. In the lower dorsal and upper lumbar part of this microcephalic cord, we have found that the position of Clarkes column is the same as in man, while according to Waldeyer, the position of Clarke's column in the gorilla's cord is transversely oval for the whole of its length. In this region, therefore, these two cords do not resemble each other. In the spinal cord of the lower apes, however, in the upper and middle dorsal regions Clarke's column has a similar position to that found in the gorilla, but at the lower dorsal region it gradually passes away from the central canal, and takes up a position exactly similar to that found in man. In other particulars the spinal cord of the lower apes closely resembles that of the higher apes. It is to such a cord (i.e. of the lower apes) that the microcephale be bears a resemblance, rather than to the higher apes. Before we discuss this resemblane, however, we must understand what has happened in this case; the development of the microcephale has originally proceded along perfectly normal lines. Somewhere about the fourth month or so, it has been profounded altered, and if the cord were now to follow along the line of development which has been taken by the apes, we should expect to find, not the pure characteristics of the cord of the ape, but the resulting effect of the superposition of these characters upon an already partially developed human cord. This is exactly what we do find, and such a view will explain all the peculiarities of shape, etc. which we have already found to be the case. Thus, we see at a glance, how it is that all the previous observers have failed to detect any resemblance between the cord of the microcephale and that of the apes, since, first, they sought for "pure" characterictics, and secondly they used for their comparison, the cord of an anthrapoid ape instead of a lower ape.

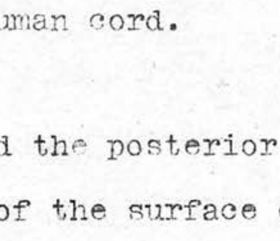
We shall now proceed to work out the points of resemblances between these two cords, lookimg, not for actual similarity of structure, but for what we should expect to find if the ape structure had been superposed on the already partially developed human cord.

3. <u>The posterior horns</u>.

In the ape cord the posterior horns are greatly shortened and fall far short of the surface of the cord. We ha have seen that the posterior horns have been reduced in size throughout the whole region of the microcephalic cord. The following two figures are from the sixth dorsal segment of a human cord and of the microcephale, and I think it will be at once seen that the reduction in the posterior horns is very marked indeed.



Man.



Microcephale.

4. Equal depth of the antero-mesial and postero-mesial furrows

In no part of the cord of this microcephale do we find any appearance of a nearly equal depth of the antero-mesial and postero-mesial furrows. This, however, could scarcely be expected. We shall afterwards see that the posterior columns must have been well formed and medullated before any arrest of development had occurred, and if after this any attempt were made to equalise these the lengths of these two furrows, it could only be done by a direct passage backwards of the crescents and the grey commissure. But the presence of the medullation of the posterior white columns would resist and quite prevent any movement backwards of the grey commissure and central canal. There would, however, be no similar resistance to the movement backwards of the ant. cornua and grey matter, and thus a relative displacement of the position of the anterior cornua in regard to the central canal and grey commissure must result. As this is exactly what has occurred, it must surely indicate that an attempt has been made to equalise the depth of the anterior mesial-~~furrow~~ and postero-mesial furrows and been unsuccessful, probably on account of the reasen mentioned above. If this view be correct, we should expect to find that the displacement backwards must be most marked where the difference between the position occupied by the grey matter in the ape cord is most markedly different from man, namely in the middle dorsal region, which we have found actually to be the case.

5. The position of Clarke's column.

Since the difference in the position of this group in man and in the apes is so very distinct, it is a point of very great importance to determine the exact position which the column of Clarke occupies in the microcephale. Before proceeding to do so, we must remember that in the cord of the gorilla, as figured by Waldeyer, the column of Clarke assumes a transversely oval outline, throughout the whole of its course, while in the lower apes it occupies this transverse position in the dorsal region only, and as we pass down the cord to the lower dorsal and lumber region, about the tenth dorsal segment, it alters its position, passes further a away from the central canal, and, its long axis rotating round, comes to occupy a position similar to that found in man. It is, therefore, to the cord of the lower ape that we must compare our microcephale. We have seen that the attempt made by the microcephale to push his central canal and grey commissure backwards to occupy the same position as in the ape, has been unsuccessful owing to the presence of the well formed posterior columns at that date, and had only resulted in a lateral and backward displacement of the grey matter of the crescent. If this lateral displacement be really due to an attempt on the part of the microcephale to superpose the structures characteristic of the ape's cord upon an already partly developed normal human cord, all the other points of difference must also take part in the change, especially there would be an attempt on the part of the column of Clarke to approach nearer the central canal and to assume a typical transverse direction.

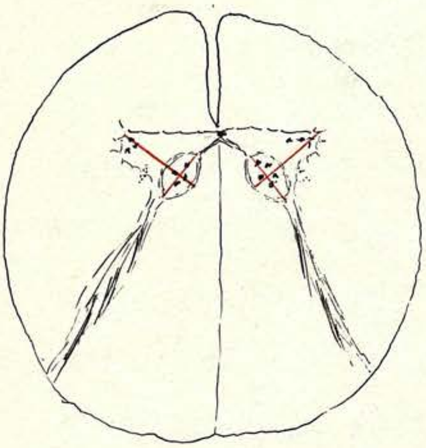
There are, therefore, three great influences at work in determining the peculiar change in the position of the grey matter in this cord, namely;-

I. A backward movement of the grey commissure;

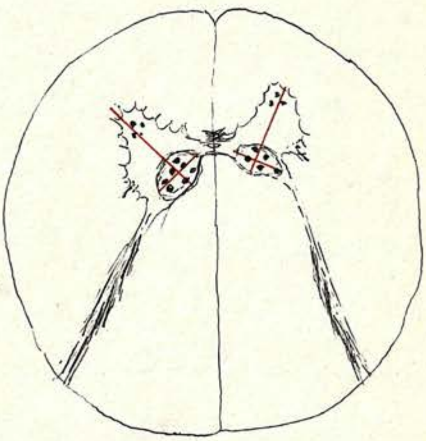
2. A corresponding backward displacement of the grey crescent.

3. An approach of Clarke's column to the central canal and an attempt to place its long axis in the transverse direction.

We have already found that, owing to the presence of the posterior columns, the first of these three factors may be left out of consideration, and thus we have only to deal with the result which such a displacement would cause in the relation of the second and third factors to each other and to the surrounding structures. Although in the ape, Clarke's column is situated at right angles to the antero-mesial and postero-mesial furrows, we may also regard it as being situated at right angles to the long axis of the anterior cornua. The failure of the central canal to move backwards so as to occupy the normal position found in the ape, would prevent Clarke'S column also from occupying a transverse position, and thus we could not reasonably expect to find Clarke's column lying with its long axis transverse; but there would be no reason why the relation of the column of Clarke to the long axis of the anterior corna should be atlered, as the anterior cornu is free to move. This is exactly what we do find, throughout the whole of the middle dorsal region,- the position of Clarke's column has been shifted nearer to the central canal, and as it could not place itself in the typical transverse position at right angles to the long axis of the anterior horn, the anterior horn has altered its position and placed itself at right angles to the long axis of Clarke's column. I think that this will be seen very clearly in the two following figures which are from the sixth, and ninth dorsal segments respectively.



D.6.



D. 9.

We have thus a complete explanation of these extraordinary changes which we found had occurred in the cord of the micro- -cephale in the middle dorsal region in particular.

It will now be noticed that, in all the points of difference between the spinal cord of the apes and of man, the microcephale exhibits in the most beautiful manner exactly what we should expect to find if we superposed these changes which we know are characteristic of the spinal cord of the ape, upon an already partially developed normal human cord.

WE have, however, a most beautiful confirmation of the correctness of this view. It will be remembered that in the cervical enlargement we noted a very peculiar atrophy of the cells of the upper antero-lateral group, the lower antero-lateral group not being similarly affected. This is a condition which has never been described before, and of which it is extremely difficult to understand the cause. The following explanation fits the case so perfectly that, I think, there can be very little doubt of its being correct. In the cord of the lower apes there can only be one antero-lateral group of nerve cells which is represented in man by the lower antero-lateral group. The upper antero-lateral group in man must therefore be a later addition. If the spinal cord of the microcephale originally developed along purely normal human lines, we should find that both antero-lateral groups would develop as usual. If an arrest of development now were to occur and the spinal cord to completely alter its course of development and proceed along entirely new lines, namely that taken by the apes, there would be no necessity for this upper antero-lateral group of cells and thus they would simply atrophy. This is exactly what has occurred, the cells of this upper antero-lateral group have actually atrophied, they have not degenerated.

It will now be clear that there is not a single point in the spinal cord of the microcephale where we could expect to find a resemblance to the corresponding structures in the cord of the ape, where we do not find a most marked change, and, from a careful consideration of the facts which I have just set forth, it is reasonable to conclude that the statement is quite justified and proved that the spinal cord of the microcephalic idiot is primary affected, quite apart from any secondary changes due to its brain connection; and that, what has actually happened, is that the development of this cord has at first proceeded along perfectly normal lines; a sudden change has then occurred, and the development has completely altered, and followed out an entirely new line, namely, that taken the the apes.

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Description of the <u>cranial nerves</u>
of the

Microcephalic Idiot.

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The Cranial Nerves.

To the naked eye, the cranial nerves appeared as large as normal, and gave a curiously incongruous look to the base of the brain. More especially is this the case in the third nerve, which on account of its size looks quite out of p ~~place as~~ place as it emerges from the diminished crura.

<u>XII th. Nerve.-</u>

The nucleus of the hypoglossal is well developed. It is situated in the normal position close to the posterior longitudinal fasciculus. The cells are quite as numerous as normally found, and are large, with a central nucleus, well marked Nissl granules and numerous processes. The division into three columns is well marked. (The nucleus of Roller is present). This nucleus, although a purely motor one, does not show any changes in the number or character of the cells comparable to those found in the motor cells of the anterior cornua of the cord. The roots follow the normal course and leave the medulla on the outer side of the anterior pyramid.

<u>XIth. Nerve.-</u>

Spinal part;- This nucleus, we have already seen, occupies the usual position in the anterior cornua of the cord, and shows the same changes as are characteristic of the motor cells of the cord, viz.- small number of cells, diminution in size, etc.

The bulbar nucleus is quite normal, both in character and number of cells.

Thus, only the lower nucleus of the spinal accessory has been affected.

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Xth Nerve, IXth Nerve.

The dorsal nucleus is quite well developed. The cells are as numerous as usual.

The arcuate nucleus is well-marked and found in the normal position. The cells stain well.

The fasciculus solitarius is large. The fibres are strong, well medullated, and stain deeply. The upper sensory nucleus and descending nucleus are well formed.

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VIIIth Nerve.-

Cochlear division;- The acoustic tubercle and the accessory nucleus are both well formed. The cells are quite numerous and normal. The trapezium is well marked and intersects the fillet. The superior olive and nucleus of the trapezoid appear to me to be normal in size. The trapezoid fibres do not extend lower down than the transverse fibres of the pons, and thus do not appear on the surface of the medulla. Owing, however, to the poor development of the deep transverse fibres of the pons, the ~~deo~~ lower trapezoid fibres lie directly in contact with the pyramidal strands.

Vestibular division;- The principle and descending vestibular nuclei are well formed. The descending root is well medullated, the fibres are strong and stain darkly by the Weigert-pal method. It can be traced as low down as just a little above the upper level of the decussation of the pyramid. The nuclei of Deiters and of Bechterew are both strongly marked.

VIIth. Nerve;-

The facial nucelus is well formed. The cells are quite normal The roots of the nerve are well medullated and strongly marked. I do not think, however, that they are unusually strongly marked.

VIth. Nerve;-

This nucleus is also well formed, large and in the usual position. cells numerous and stain well. Fascicles strong and well medullated. They mostly pass along the inner side of the pyramidal strands, but a number pass through the pyramidal fibres and a few pass along the outer side of the pyramids.

Vth. Nerve;-

This nerve is well developed. The principal sensory and descending nuclei are well formed; the descending root is well medullated and can be traced as low down as the lower part of the decussation of the pyramids. The principle motor nucleus is as well marked as the as the sensory nucleus, while the ascending root is well medullated and the superior motor nucleus stains well shows the typical nature of the cells, and can be traced as far up as the trochlear nucleus.

IVth. Nerve;-

The trochlear nucleus is well developed and normal in position. The fibres are well medullated, and the decussation takes place in the mesial line.

IIIth. Nerve;-

The oculomotor nucleus is well formed. The fibres are large, well medullated, and do not appear to be at all diminished in number. Owing to the poor development of the crusta, there is scarcely any sulcus oculomotorius and thus the nerve appears to emerge from an almost flat surface.

It will be seen from the above account that the cranial nerves, are all quite normal, and that the motor cranial nuclei are as well developed as the sensory, and do not show any similar changes to those we found in the motor cells in the cord. The difference in the two spinal accessory nuclei is well marked, and supports strongly the fact that this nerve is essentially a motor spinal nerve. In connection with the dorsal nucleus, we found that the intermedio-lateral tract was well developed in the cord, and if this is really an extension upwards of this tract, we should expect to find it also normal.

The posterior longitudinal fasciculus is well developed, well medullated and stains darkly.

The bundle which is stated to pass from the pyramidal strands in the crusta to the mesial fillet, and to represent the cranial path is not present in this case.

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I have been quite unable to discover any points of similarity in the cranial nerves of the microcephale to those of the anthropoid apes which are altered from the normal human type. This, however, is exactly what we should expect to find, since by the fourth month of development, the cranial nerves, both motor and sensory, have become medullated (See "Mid and Hind Brain", by Bruce) and thus the course of their fibres has been determined before the alteration in the normal development has occured.

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Description of the medulla oblongata, pons Varolii, mid and hind brain of the microcephalic idiot.

Medulla Oblongata.

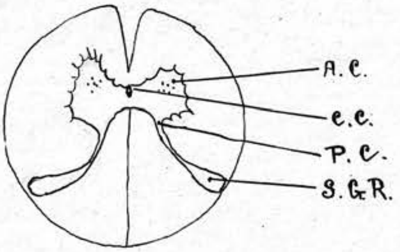
Naked-eye appearance;-

The medulla is large in comparison with the pons and mesencephalon. This is quite what might be expected. The diminution in the two latter is in the crustae and ventral parts respectively, and these form large portions of these sections of the brain in normal conditions. The parts in the medulla corresponding to these subdivisions in the pons and mesencephalon, viz.- the ventral portion, are relatively small but their reduction does not materially affect the size of the medulla as a whole.

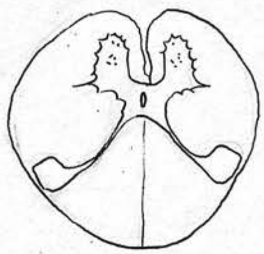
The olivary eminences are also small, and the super--ficial anterior arcuate fibres are not present, except in minute numbers. The anterior fissure is consequently quite open and not blocked up by arcuate issuing fibres. The distinctive character of the medulla is the relative large size of the restiform bodies relatively to the pyramids and olives - in fact they do not appear to be reduced at all. - The restiform bodies bulge out beyond the olives to a large extent, and are as large as the middle peduncle.

Microscopic;-

First cervical segment:- Here, again, we find the same deviations in structure from the normal as we have already seen in the lower cervical segments. In outline, the section is round; the posterior median furrow is twice as long as the anterior median fissure. The central canal is elongated from before backwards. The white matter does not stain equally by the Weigert-Pal method, The column of Goll is not so darkly stained as the column of Burdach, while the tract of Gowers stains still more lightly than in the third cervical segment, due, no doubt, to the diminution in the amount of medullation in the more distant parts of the fibres. Helweg's tract, on the other hand, does nor stain so lightly as in the third cervical segment, since as this is a descending tract, we are now nearer to the proximal end of the fibres which are better medullated.



Microcephale.



Normal.

The chief differences between the microcephale and the normal human cord at this level are -

I. The small posterior horns , and markedly reduced subst. gel. Rol.

2. Half of the grey matter of the anterior horn is situated behind the level of the ant. grey commissure

3. The grey matter round the central canal is reduced in amount.

The small size of the spinal accessory nucleus, and the great diminution in the number of cells present, is very marked

The structure of the medulla can best be demonstrated by the description of thrwee sections, viz.-

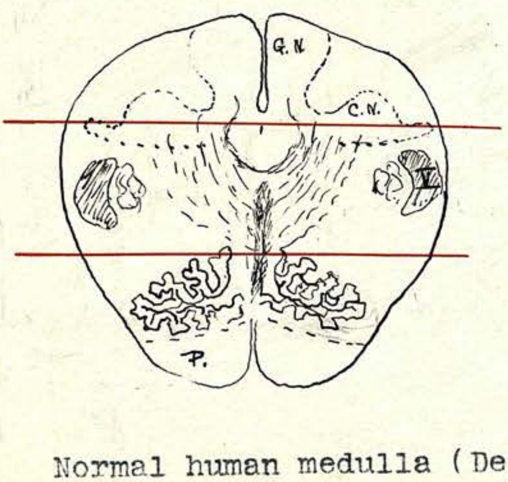
I. At the lower level of the olive;

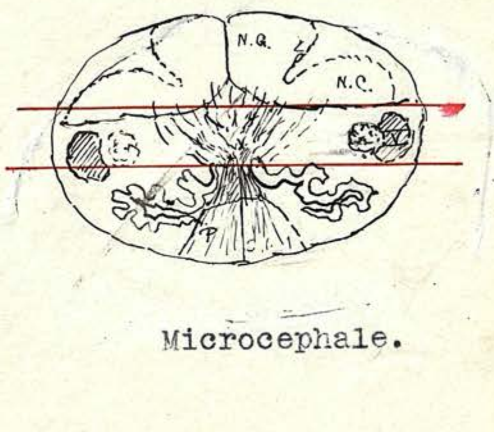
2. At the middle of the olive;

3. At the upper end of the olive.

At the lower end of the olive, the medulla is flattened from before backwards. This is due to several causes; first, the poor development of the pyramidal fibres results in only a small projection, and as the olive is also reduced in size, t this is still further lessened. If we follow the decussation of the pyramids, we find that it is poor, and the detached horn of grey matter cannot be traced very far upwards. The cuneate a and gracile nuclei are strongly developed. An external cuneate nucleus is present. The gelatinous substance of Rolando also increases rapidly in size, and the descending root of the fifth nerve is well marked. The grey matter round the central canal is slightly smaller than usual, and the formatio reticularis is also diminished in amount. Thus, as we pass up into the medulla from the first cervical segment, the change which has resulted is chiefly in a small ventral part (due to the poor pyramidal strands), a small middle part (due to the smaller formatio reticularis), and a strongly marked dorsal portion ((due to the large nuclei of the post. columns.) As the structures internal to these nuclei are not well developed, the result has been that the gracile and cuneate nuclei do not form any marked bulging on the surface, since this has occurred internally rather then externally. The subst. gel. Rol. also has been pushed further out to the side and backwards, in as the result of the size of these two nuclei, which at this level occupy about one third of the section. As we should expect, the deep arcuate fibres are very numerous, and the decussation of the fillet well marked.

A section through the middle of the olive about the lower extremity of the restiform body shows an appearance very similar to that normally found. It is, however, more flattened. If we divide the section into three parts by two lines one joining the anterior margins of the two cuneate nuclei, and the other the posterior margins of the inferior olive, we find that the three parts are nearly of equal width from before backwar. In the normal ~~cord~~ medulla the middle portion is almost as large as the other tw and thus it is the diminution in the part of the medulla between the olivary nuclei and the posterior column nuclei which has caused this flattened appearance. In the normal cord these three portions are of nearly equal breadth from side to side, while in the microcephale, the posterior part is broadest, the middle part is narrower, and the anterior part still narrower.





Microcephale.

Normal human medulla (Dejerine).

If we now examine a section through the upper end of the olive, or better still, about the level of the upper third, it will be seen that the appearance is very similar. In order to determine where exactly the differences lies, I Have projected a drawing of the microcephale on to a similar drawing of a normal medulla at approximately the same level. This shows at a glance, that the greatest difference is in the smaller size of the inferior olive in the microcephale. The pyramids are also reduced. The reduction in size of the formatio reticularis has gradually disappeared, and at this level it is very nearly normal in amount. The restiform bodies have scarcely been reduced at all, and the cuneate nucleus extending into the dorsal part of the restiform body, is partly responsible for their non-diminution in size. There must, surely be a diminution in the number of fibres in the inferior peduncle, since the cerebellum and olive are both reduced in size, and there are no superficial arcuate fibres. This last fact is one of very great importance. There is also no arcuate nucleus. The anterior superficial arcuate fibres and the arcuate nucleus are both absent in the anthropoid apes, and this constitutes a very important resemblance between the medulla of the microcephale and the anthropoid. It is all the more important that this absence of these fibres cannot be possibly secondary to changes in the cerebrum. It is essentially a ~~r imr~~ primary change. These fibres arise from the nuclei of the posterior columns, which we have found were extremely well marked and it is not thus possible to account for their absence as the result of a change in these nuclei.

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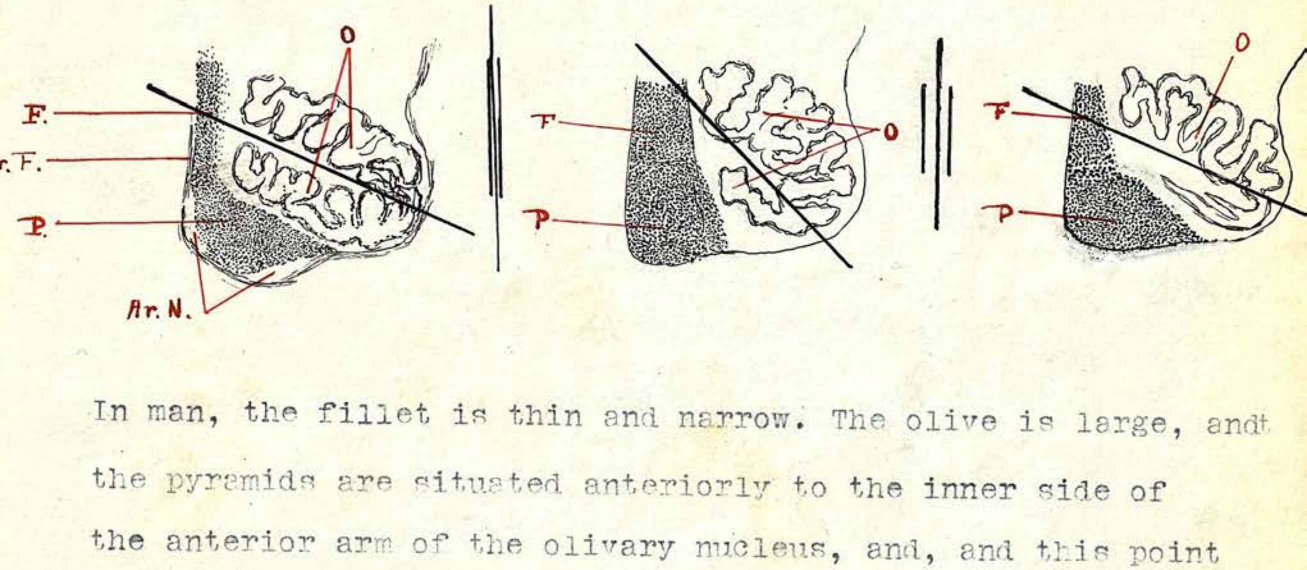
This is, in fact, a point of very great importance. It means that we have had the medulla affected primarily as distinguished from secondary changes. It means that we have a similar change in the medulla to what we found to be the case in the spinal cord; they have both been individually affected, quite apart from changes in the cerebrum. But there is also another proof that the medulla has been primarily affected, namely, the position and form of the olive in relation to the fillet and pyramids. In the chimpanzee, we found that the relation was different from that found in man. The relation in the three cases is best shown in the following figures;-

Man. Chimpanzee. Microcephale.



In man, the fillet is thin and narrow. The olive is large, andt the pyramids are situated anteriorly to the inner side of the anterior arm of the olivary nucleus, and, and this point is important, the two arms of the olive are of nearly the same length and the inner margins of both arms are equidistant from the middle line. (See figure). In the chimpanzee, the fillet is shorter and broader, and its anterior end is of the same breadth as the posterior margin of the pyramid, in fact, it is difficult to tell where the one ends and the other begins. The pyramids, instead of being triangular in shape, as in man are quadrilateral, and are situated to the inner side, not anterior, of the olive. And, the two arms of the olive are of unequal length, the posterior arm being three or four times longer(or, measured in a straight line, twice) as long as the anterior arm. In the microcephale, the fillet is intermediate in shape to that found in man and in the anthrapoid ape, and the anterior arm of the olivary nucleus, is only half the length of the posterior arm. The posterior arm is highly convoluted, the anterior arm is almost straight. We have thus here, a second primary change, and of a very remarkable and striking nature. The position of the long axis of the olive is different in man and in the chimpanzee, and the position of the axis in the microcephale coincides with that found in ma man. This however, again is exactly what we should expect to find. At the fourth month of foetal life the olive has already been laid down, and the direction of its long axis fixed. It is difficult to see how this could be altered, and actually is not. But at such an early age, the convolutions of the olive olive are very poorly developed, and if the change in development occurred early enough, probably no convolutions would be present at all. But although the change in development could not affect the axis of the olive, it could easily affect the relative growth and crinkling of the grey matter, and as the proportional lengths of the two arms are different in the apes, though equal in man, if the development after the arrest had taken place, should proceed along the lines followed by the apes, we should expect to find this unequal proportion between the two arms, which is exactly what has occurred. It is, if anything, a more remarkable proof that the development of the medulla of the microcephale has been _primarily_ affected, than even the absence of the superficial arcuate fibres and the srcuate nucleus.

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Description of the cerebellum, pons,
mid and hind brain
of the microcephalic idiot.

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The Cerebellum.

The flocculus is very large, relatively to the size of the cerebellum.

The horizontal fissure appears unusually high, so that the upper part of the cerebellum seems smaller than natural.

The tonsils are very small, the right one being scarcely recognisable from the surface.

The folium cacuminis is not developed.

The two sides of the great horizontal fissure are continuous across the middle line.

The poor development of the postero-superior and postero-inferior lobules is most noticable.

The Pons Varolii.

Naked-eye appearance;-

The want of prominence of the pons is very marked, and is to be associated with the diminished cortex. The superficial part of the pons is the link between the cerebral and cerebellar cortices, the nucleus pontis acting as an internode. The small size of the middle peduncles of the cerebellum is striking, and in harmony with this view. It is worthy of note that it is the fibres of the upper part which are chiefly absent. The fifth nerves comes out through the upper border of the crus, and thus the middle peduncle appears to enter the cerebellum between the facial and auditory nerves below and the fifth above."

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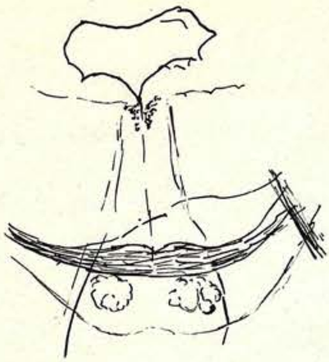
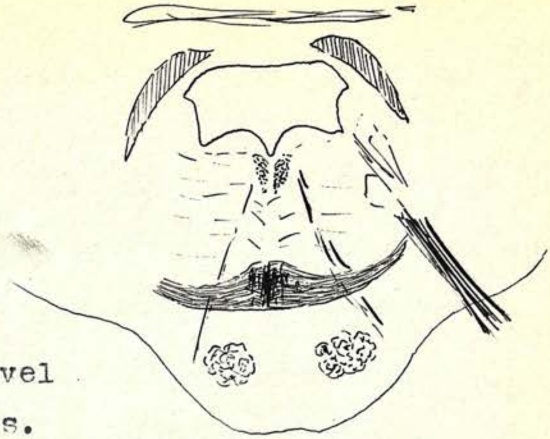
The great diminution in size of the pons affects almost entirely the ventral portion, which is reduced to an extraordinary extent. We have seen from the above that the transverse fibres of the pons are reduced in number from above downwards, but they sre also reduced from before backwards to an equally remarkable degree. This reduction has affected both the superficial and deep transverse fibres. AS we follow up the pons in serial sections, we find that the deep layer of fibres has been more reduced than the superficial layer. The greater part of the deep transverse fibres of the pons are are wanting throughout the whole of the extent of the pons; while although the superficial fibres are also reduced to a d degree, this reduction affects mostly the upper transverse

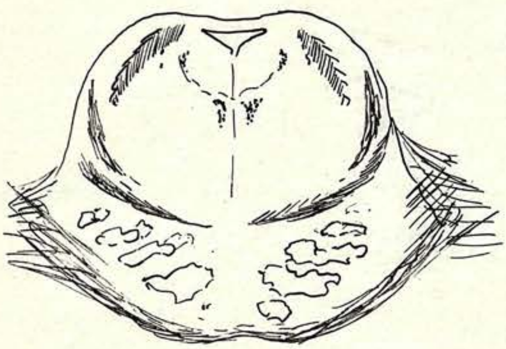
Microcephale.

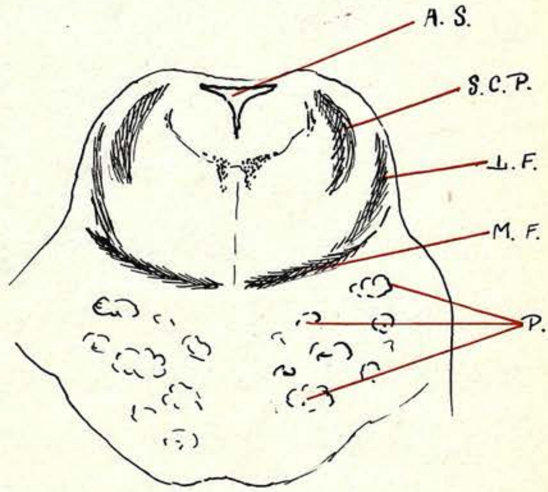
Normal.



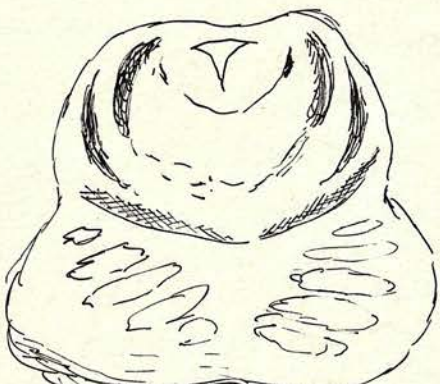


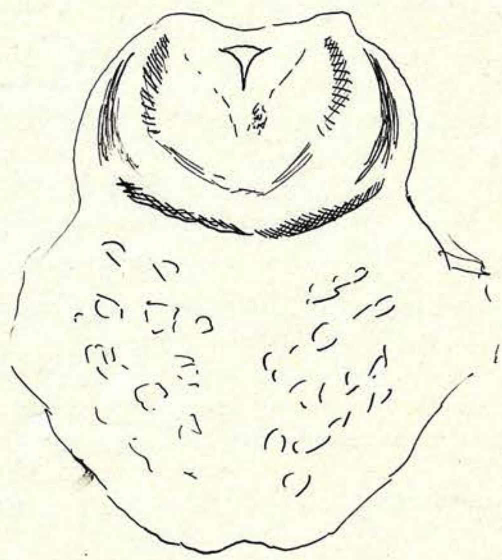
Lower level of pons.





Middle of pons.





Upper level of pons.

superficial transverse fibres. Associated with this reduction in the number of transverse fibres, there is a reduction in the nucleus pontis. The pyramidal strands are not broken up into separate strands to the same extent as usual, and in the middle o of the pons they occupy the same shape as in the crusta. Before we work out a complete account of the relation of the fibres of the crusta to this reduced pons, it will be best to study the alteration which has occurred in the crusta itself.

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The mesencephalon.

Viewed from the basal aspect, what strikes one most is the shallowness of the interpeduncular space. This is largely due to the want of prominence of the crustae of the cerebral peduncles and of the pons Varolii. Even at the place where the crustae join the pons they are separated from each other by a considerable interval (6mm.). This diminution in the corticifugal fibres of the crustae is due to a loss of fibres of all sets corresponding with the areas of cortex they represent.

The small size of the two corpora mammillaria within the interpeduncular space is also noticable.

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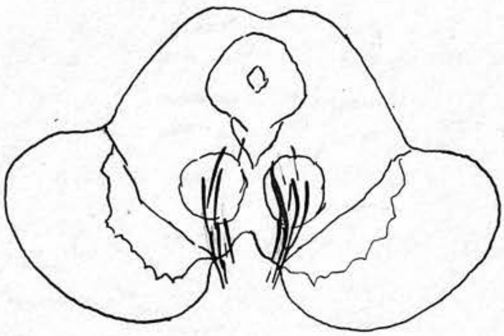
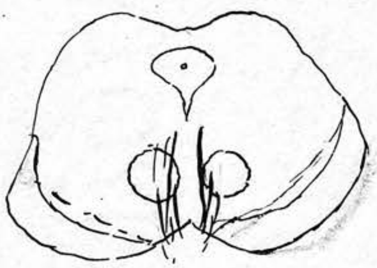
A transverse section of the mid-brain stained by the Weigert-Pal method shows that the great reduction here has taken place in the ventral part of the section, and has affected particularily the crustae, which are in consequence very much reduced in size. In order to see clearly how great a reduction has occurred as compared with the normal, I have ~~drawn out a copy~~ traced a drawing

~~of~~ from Dejerine, which represents the typical normal condition, and it will be seen at once that the reduction is very great and has affected the whole of the fibres of the crusta.



Dejerine. p. 89.



Microcephale.

Besides this, however, a Weigert-Pal section shows that the outer and inner fibres are especially reduced in amount, and what is still more marked, those which are present are exceedingly poorly medullated, and stain very lightly indeed. In order to understand what has happened here, it will be best to give a small description of the view held at present as regards the origin and course of these fibres.

The view held by Dejerine, and admitted by almost everyone, to be correct, about the origin of the fibres in the crusta is as follows;-

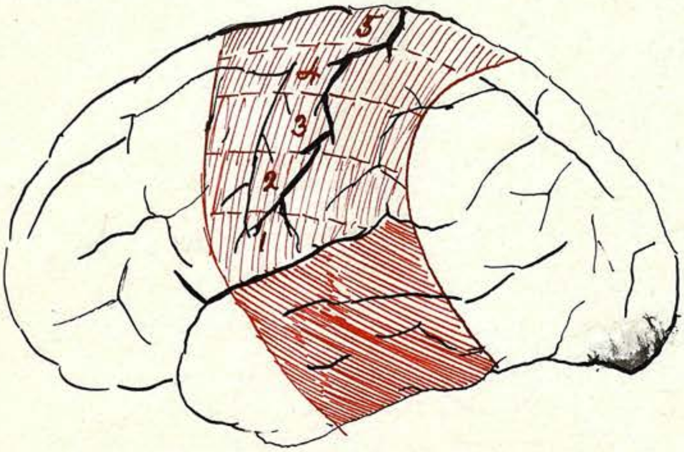
The whole of these fibres are the axons of cells situated in the cerebral cortex. He accordingly divides the crusta into five portions (see next page), and, of these he traces the outermost one, or "faisceau de Turc", from the middle of the second and third convolutions of the temporal lobe. They descend along the posterior part of the posterior segment of the internal capsul capsule to the crusta, where they occupy the outer fifth. They terminate in the postero-superior part of the nucleus pontis.

The inner fifth, or "faisceau interne" receives its fibres "de l'opercule rolandique et de la partie adjacente de l'opercule frontal, c'est a dire de la zone motrice facio-pharyngo-laryngee".

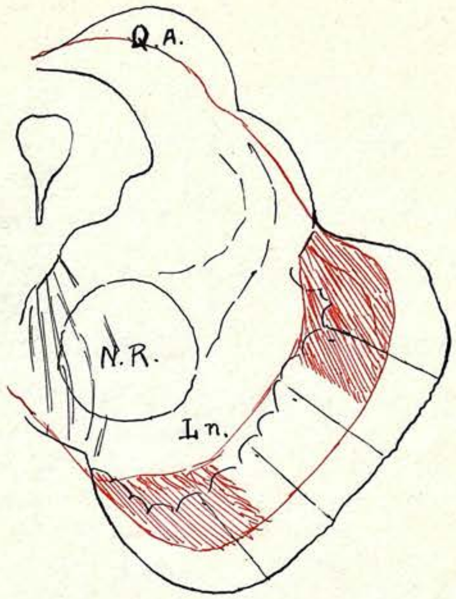
The middle three fifths is constituted by fibres which arise from the upper ⅓ of the Rolandic area, and part of the frontal and parietal convolutions adjacent. (See figure). The fibres of the middle part of the Rolandic area form the second and third internal fifths, and the fibres of the superior part of the Rolandic area and of the paracentral lobule pass to the second outer fifth.

In order to which of these groups the poorly medullated fib fibres in this case belong, I have projected a drawing of the crus crusta of the microcephale on to a drawing of Dejerine. (See Fig). This shows at once that the whole of the "faisceau de Turc" has been affected, and also a part of the second internal fifth portion. And, also, that the inner fifth, and a portion of the second inner fifth have also been similarly affected.

To show the connections of the cerebral cortex to the crusta.



Dejerine p.77.



In this diagram, the black is a typical normal case as traced from a drawing of Dejerine, while the red represents the microcephale enlarged to a similar amount and drawn on the top. It shows very clearly, the reduction in the crusta, and also that it may be roughly divided into three parts, the outer and inner of which are poorly medullated. Before we can completely understand these changes, it will be necessary to know the changes in the cortex in the brain. Still it is very similar to the appearance presented by the chimpanzee, only the two cases are not exactly parallel, since the fibres from the frontal "Eye" area pass down the inner side of the crusta in the ape, and are absent in man.(Dejerine). The fibres of the inner fifth, we know, come from the opercula, which are absent in the apes, and thus if they were first formed in the microcephale before the change in development took place, the result would be to prevent any further growth. (Compare the upper antero-lateral group of cells in the cord).

We shall now try and see how we can correlate the absence of the transverse fibres of the pons with these facts. Dejerine states that the "faisceau de Turc", ends in the postero-superior part of the nucleus pontis. We have seen that ~~in this case~~ it is very poorly developed in this case, it fact, it is almost absent. If we trace the "faisceau de Turc" downwards by serial section, we fin which we can do very easily, since owing to the few fibres which pass amongst the pyramidal strands, they retain the same position as in the crusta, we find that the fibres of the faisceau de Turc disappear very early, so that they evidently do not pass very far down into the pons. The fibres of the second outer fifth, however can be traced to the postero-inferior part of the nucleus pontis, where this disappear, and thus they must end here.

The fibres of the inner fifth, cannot be traced far down into the pons, and it would seem the the great loss of fibres in the upper superficial part must be associated wi with this, i.e. the fibres of the inner fifth end in the antero-superior part of the nucleus pontis. The fibres oft the second inner fifth must end very close to these last, as we cannot trace them very far down, they cease a little below the middle of the pons. We have thus been able to map out roughly the ending of these different fibres in the nucleus pontis. (It is also worth while comparing the poor development of certain parts of the cerebellum, already described, with the absence of certain of these fibres).

The dentate nucleus has quite a different appearance on the two sides; on the one it does not differ very mu much from the normal appearance, while on the other it is unusually large, wavy, contains very few fibres passing through it, and is not sharply differentiated o off from the surrounding tissues.

The superior cerebellar peduncles are diminished in size. They do not stain equally all over by the Weigert-Pal method, curious patches appearing towards the dorsal part, which are constant when followed through serial sections. The ventral part of the superior cerebellar peduncle is certainly diminished in size, when compared with the illustrations of Dejerine on this subject, and so also, I think, is the red nucleus. (This is of interest as we found in the cord that the prepyramidal tract was probably affected).

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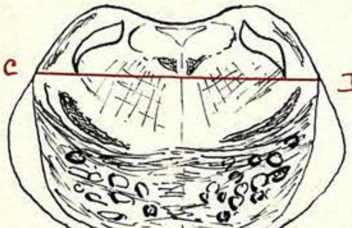
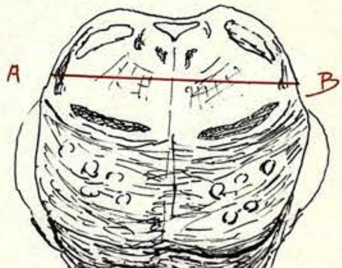
The tegmental part of the pons.

The tegmental part of the pons is principally occupied by the nuclei of various cranial nerves, which we have already found were all well developed, and had apparently suffered very little, if any diminution. We should therefore not expect to find any great change in the tegmental part of the pons; neither do we find any. The principal variation from the normal consists in the fact that it appears to have been flattened from before backwards, which we also saw was characteristic of the medulla, and is also present in the mesencephalon. In the lower part of the pons, the tegmental part seems all out of proportion to the ventral part, being almost twice as thick; about the middle of the pons, the dorsal and ventral parts are of about equal widths, while at the upper level of the pons, the dorsal part again becomes wider. The appearance is just as if the full growth of this part had never been completed fully. and that the determining part of the shape had been the amount of development of the cranial nerves. We thus find it is thick in the lower portion where the nuclei of the sixth and seventh nerves are situated, and where the trapezoid fibres of the eighth are found, but as we pass above these structures the shape has next been determined by the fifth nerve. This is situated to the side of the dorsal part of the pons and thus has not tended to cause any increase in thickness from before backwards, but instead has caused an increase in width from side to side. When we pass above these nuclei of the fifth nerve, we again get a reduction in the size of the dorsal part of the pons, which however, does not last long as the lateral fillet soon forms a compact mass on the lateral side of the tegmentum, and, as it is well developed and the nucleus is large, it again gives a marked projection to the side of the tegmentum and gives to it the appearance as if it had been flattened from before backwards. Of the structures which are present in the lower part, we find that the mesial fillet is well marked and large, the posterior longitudinal fasciculus well formed and darkly stained and the superior olive well formed. As we gradually pass up into the tegmentum of the mesencephalon we find the superior cerebellar peduncles come into view. They are both reduced in size, but the reduction is most marked in the right side. Owing to the ~~lateral~~ marked flattening of the tegmentum the ventral end~~s~~ of the peducles are pushed outwards and the flattened appearance becomes even more marked.

Microcephale.



Normal.



Note the greater length of CD in the microcephale to AB in the normal.

We again find that the resemblance between the pons of the microcephale to the pons of the ape is evident. In the ape the peduncle of the flocculus is well marked, and the flocculus is larger in comparison to the rest of the cerebellum than in man. In the microcephale, although the peduncle of the flocculus is not very marked, yet the flocculus is large compared to the rest of the cerebellum.

In the ape the ventral part of the pons and the crustae are smaller in proportion to the tegmentum than in man. They certainly are smaller in the microcephale, but as this diminution in size is largely secondary to changes in the brain, I shall not discuss the matter, but content myself with pointing out that the poor medullation of the fibres of the inner and outer sides of the crustae, and as these two groups of fibres are much more poorly developed in the ape than in man, we may have here a condition somewhat similar to the atrophy of the upper antero-lateral group in the cervical region of the cord.

The question of the shape of the tegmentum is rather a di difficult one to explain, basause first, the difference is not so very marked, and secondarily, it is a question of development, on which the literature is rather scanty. The explanation is probably something like this;- We know that the cranial nerves medullate early, far earlier than the formatio reticularis and must thus be a determining factor in the shape of the tegmentum. At the fifth month the formatio reticularis is not well marked, and thus would have been affected by this arrest in the normal develop--ment. In the ape, the formatio reticularis is smaller relatively than in man, and thus when the development proceeded along the new lines, there would result a relatively smaller formatio reticularis than is normally found, except where the cranial nerves are placed and there will be a marked increase in size, either in the antero-posterior direction or in the lateral direction according to the position of the nucleus.

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The tegmental part of the mesencephalon.

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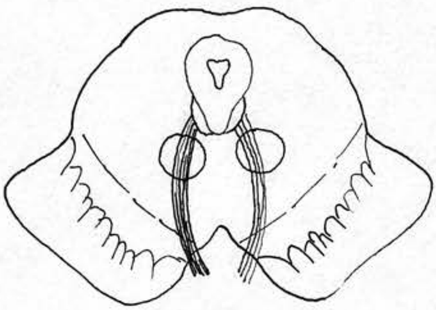
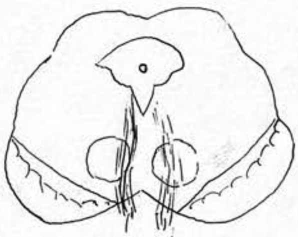
As we have already see, the great change which has taken place in the mesencephalon, is in the reduction in size of the crustae. (See figures below).





As a consequence of this, the sulcus oculomotorius and sulcus lateralis have almost both disappeared
The inferior and superior quadrigeminal bodies are less prominent than usual.
As we pass upwards we begin to find that the gray matter becomes altered; it appears to be unable to differentiate sharply the various structures which are formed from it, and these, in consequence, become confused, badly formed and not sharply marked off from the surrounding structures. The beginning of this alteration in the gray matter, can be be seen as low down as the decussation of the pyramids, where the gray matter round the aqueduct of Sylvius increas in amount and as we pass up, compresses the Aqueduct so much that it becomes narrower, and finally almost occluded altogeth altogether. A similar increase of gray matter is to be found between the crusta, which, as it is traced upwards

increases more and more, so that the corpora mammillaria, instead of standing out as two round projections, become about three-quarters embedded in gray matter. This increase in the gray matter, by filling up the hollow between the two reduced crustae is partly responsible for the peculiar appearance of flattening seen on the base of the brain.

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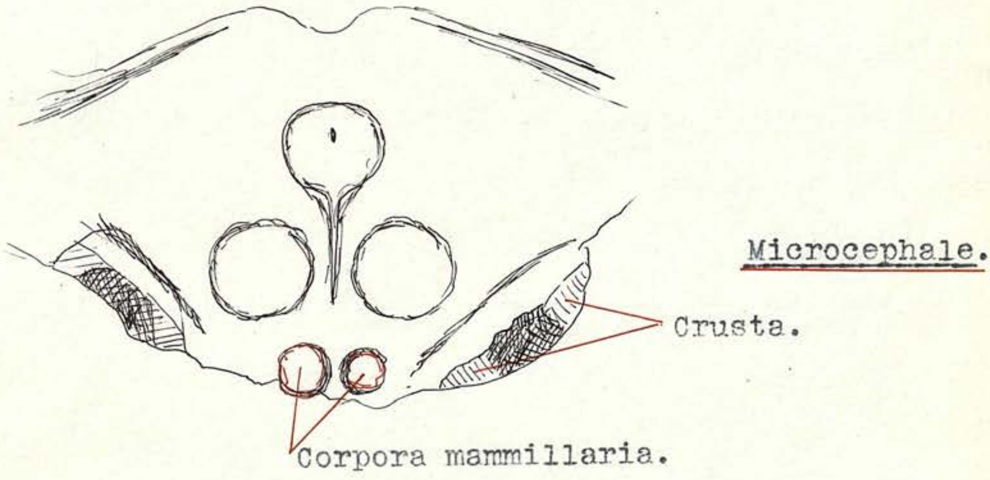

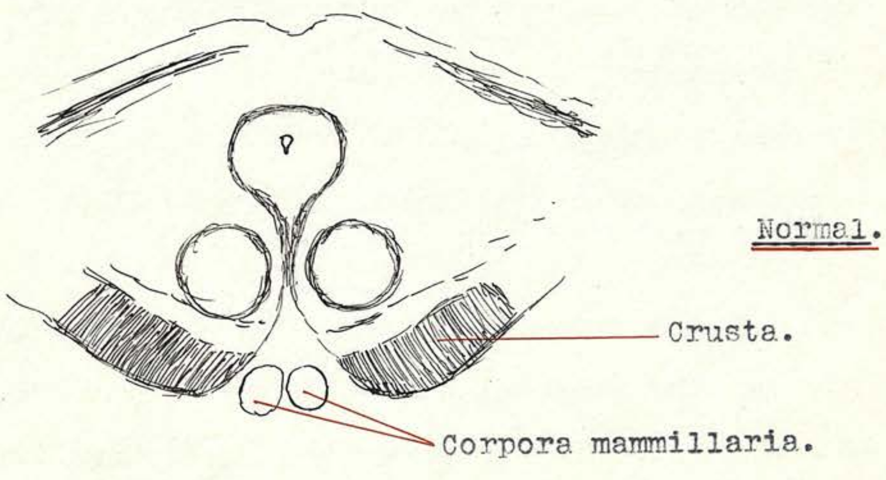

Conclusion

1. The spinal cord of the microcephalic idiot is reduced in size.
2. This reduction is partially secondary to the brain condition.
3. But there are also changes which are entirely independent of any changes in the brain, and are due to a primary change in the cord.
4. The white matter :

   The tract of Burdach is completely medullated.

   The tract of Goll is poorly medullated distally.

   The direct cerebellar tract is completely medullated.

   The tract of Gowers is poorly medullated distally.

   The pyramidal tract is poorly medullated distally.

   The antero-lateral descending fibres are poorly medullated.

   The tract of Helweg is very feebly medullated.
5. Nerve Cells :

   The "cervical nucleus of Stilling " cells are abnormal.

   Clarke's column from D 1 to L 1 is normal;

   from L 1 to L 3 it is abnormal.

   (This latter is associated with a deficiently medullated tract of Gowers).
6. The motor cells are reduced in number and in size and are poor in processes. They all stain well and are full of Nissl granules. The reduction in number is greatest in the lumbar region; probably it is secondary to the gradual loss of medullation in the pyramidal tract.

7. <u>Grey Matter</u> :

The posterior horns are specially marked by their great reduction, especially in the dorsal region.

The anterior horns are specially marked by their rotation outwards, so that the greater part of the grey matter comes to be behind the central canal. (Also best seen in the dorsal region).

8. The upper antero-lateral group in the cervical region has atrophied.

9. The changes found in the microcephalic cord do not resemble those found in man or in the ape. They resemble those found in the Gorilla, however, in the respect that they are found most marked in the dorsal region.

10. The ape cord differs from the human cord in three points :

    1. The greatly reduced posterior cornua ;
    2. The equal length of the anterior and posterior median fissures ;
    3. The transverse position of the axis of Clarke's column.

11. In the microcephalic cord :

    1. The posterior cornua are very greatly reduced ;
    2. The equal length of the anterior and posterior median fissures is not present, but instead the grey matter has rotated outwards and backwards to assume a mesial position ;

3. Clarke's column, although not transverse, is situated at right angles to the anterior cornua, which is the condition in the apes.

4. The upper antero-lateral group of cells in the cervical region has atrophied. It is present in man and absent in the lower apes.

12. A complete explanation of the condition is found in the <u>superposition of an ape-like cord upon a foetal three-months' cord</u>. The presence of already formed posterior white columns have prevented a greater similarity between the microcephalic and ape cords, and is the key to the changes which have occurred in the microcephalic cord.

13. <u>There is a micromyely as well as a microcephaly</u>.

14. The affection of the lower posterior roots leading to a deficiently medullated tract of Goll is a change apart from the spinal cord changes proper. (To be discussed later).

15. There is no vascular change in the cord.

The Cause of True Microcephaly.

The first of the many theories which have been put forward to explain this most interesting condition was undoubtedly that of Vogt, who considered it a case of "atavism" or reversion to an animal type, and accordingly applied to this class of individual the name of "ape-men". But as all his deductions were based simply upon a study of the skull and casts of its interior, he was quite unable to present any strong foundation for his views, and as he had based conclusions of such far-reaching importance upon such slight evidence, the natural result was a revulsion of feeling which led to a more or less complete abandonment of any such attempt at explanation.

Subsequent workers sought an explanation of the condition in some pathological lesion. Virchow considered that the growth restriction of the brain was due to a premature synostosis of the cranial bones. The fault, therefore, lay at the door of the skull, the sutures of which were supposed to close at an abnormally early period. This view is quite untenable, since it has been shown by Professor Cunningham that the growth disturbance has affected the brain at a period corresponding to the third or fourth month of foetal development, i.e., at a time when sutural closure is altogether out of the question, since at this stage the ossification of the cranial bones has only advanced to a very slight extent.

Other observers have thought the restricted brain development is the result of an insufficient blood supply. In the microcephalic skull the carotid canals are very narrow, and the internal carotid arteries are small in comparison with the vertebral arteries. This is the result of the small brain development and not the cause of it. The vertebral arteries are larger than the carotids because the parts of the brain which they supply, namely the medulla, pons and cerebellum, are less reduced in size than the cerebrum, which is supplied by the carotid. As Marchand states, it could not possibly be expected that a reduced cerebrum could be supplied by internal carotid arteries of the full standard calibre.

When this theory was discarded, observers next suggested exogenous interferences with growth. Klebs, for instance, proposed - atrophy from compression due to disease of the uterus; Gerhartz, sudden compression in consequence of a retroflexed gravid uterus; Falkenheim, injuries sustained by the uterus during its growth; alcoholism on the part of the mother, etc. All these theories are now altogether discarded, and as I shall show later, they are quite insufficient to afford an explanation of the condition.

It was next ascribed to disease of the foetus itself. Barlow proposed "foetal meningitis"; Keller "encephalitis"; Stuke "foetal illness of the brain substance", etc. But there can be no doubt of the complete failure of any such explanation to meet the case, since there is no evidence of any of these conditions in the greater number of microcephalic brains which have been examined.

Developmental defects were next considered, but these were looked upon as being due to some pathological condition. Marchand thought it was "an expression of defect of development". Chiari considered it the result of "a primary aplasia or agenesis"! Schüle called it "a modified embryonic brain", the result of an original weakness in the development of the cerebrum. Aeby thought it was due to a "deviation of the law of development of the brain". Mingazzini stated that it was an atavism, but that it was pathological defects which allowed the production of such an atavism to take place.

It will be seen from this that the gradual trend of opinion was to show that the condition could not be ascribed to any external cause affecting the brain development secondarily, e.g., premature closure of the skull, diminution of arteries, etc., and that all such changes were simply secondary to the brain condition. Because the brain was small, the arteries also were necessarily small, and the skull simply adapted itself to the size and shape of the enclosed brain. It would be quite unreasonable to expect to find a normal sized skull and a small microcephalic brain. Then after various foetal diseases had been proposed as the cause, and these had later been found to be absent, the general view gradually began to be that there was an alteration in the normal development, but why this alteration should occur was never demonstrated, although it was always considered to be due to pathological causes.

Giacomini then marked an epoch in our knowledge by dividing the brains into two great classes, those in which there was a definite pathological lesion, porencephaly, atrophy, absence of corpus callosum, etc., and those in which there was no evidence whatsoever of any pathological condition. This latter group he called "true microcephaly", or "microcephaly proper", but he considered that brains belonging to this type "always retained the human imprint" and were not to be considered as of value in the theory of descent.

Later Professor Cunningham accepted this classification of Giacomini. He had, in fact, arrived at it independently, and as the result of a most careful and complete examination of the gyri and sulci of two most typical microcephalic brains he gave the first accurate and complete account of their arrangement and their comparison with the foetal and ape conditions. As a result of this examination he proposed that the condition was far more ape-like than human. "Indeed in almost every furrow we detect some special simian character, and it is impossible to avoid the conclusion that in its fissure pattern the brain of Fred approaches more closely to the ape type than the human type, and the extraordinary point is that there is a mixture of these characters which are distinctive of a high ape with those which are distinctive of a low ape. This is most suggestive. The general arrangement differs widely from that seen in the brain of any known ape, but it presents some features which are peculiar to an anthropoid and others which are characteristic of, say, a baboon or a macaque. To what does this point ? We do not think that it is possible to avoid the conclusion that we are dealing with a case of partial atavism, or a case in which the brain, in so far as its convolutionary condition is concerned, has reverted wholly or partially to a condition in which it existed in an early stem-form".

From the results of the full examination of the nervous system of Robert Lindsay, it is possible to take another definite step forwards in our knowledge.

(True microcephaly is rarely observed early in life. Interest is not excited until several months after birth, as the condition does not interfere with post-natal life of a vegetative kind, and it is not till some months have elapsed that it is noticed that the child is mentally deficient. Giacomini observed one case out of nineteen in a new-born infant. Very little is known of the antenatal history of the microcephalic foetus. According to Ballantyne ("Antenatal Pathology and Teratology," p. 363), "it would appear that hydramnios is not an uncommon occurrence, and that family prevalence is frequent. Two microcephalics have been born to the same mother, as in Giacomini's first case (in which the birth of the second defective child was ascribed to a maternal impression received from the first). Three microcephalic brothers have been met with (J. V. Lalonde, Rev. Scient., 48, iii, 579, 1895) ; four microcephalics and a clinicephalic occurred in the same family,

(S. N. Turizzi, Atti d. Accad. Gioenia di sc. nat. in Catania, 3 S., xv, i, 1881), and in the famous Becker family there were five individuals affected with microcephaly (O. Flesch, Verhandl. d. Berl. Gesellsch. f. Anthrop., 72, 1883 ; T. L. W. Bischoff, Anat. Beschr. eines microcephaler 8-jähriger Mädchen, Helene Becker aus Offenbach Münsche, 1873 ; N. Rüdinger, Sitzungs. d. math. phys. Cl. d. k.-bayer Akad. d. Wissensch., 2, Münschen xv, 112, 1885 ; Stendel, Med. Cor.-Bl., 8, Württemb.-ärztl. Ver., lvi, 33, 1886; and others). The so-called Aztec man and woman (Indians from Mexico) exhibited in various parts of the world, were instances of microcephaly. They were married in 1867, but had no offspring (F. Birkner, Arch. f. Anthrop., xxv, 45, 1898). It has been affirmed that in one instance only has a microcephalic woman conceived, and that in her case the foetus was born dead (Ireland, in Hack Tuke's Dictionary of Psychological Medicine, ii, 807, 1892). One of Shuttelworth's patients (Journ. Ment. Sc., xxiv, 438, 1878) had consanguineous parents, and the parents' late marriage (opsigamy, as it is called) has been alleged to be a causal factor. The family history in Frey's case (Arch. f. Anthrop., xxv, 33, 1898) was interesting. There was first a normal boy, then a microcephalous boy, then triplets (a normal boy and a microcephalous boy and girl), then a microcephalous girl, and finally two normal children."

(Ballantyne considers that "the right way to look upon microcephaly is as an antenatal arrest of growth and development; as such it proves no more in respect to the primal origin of man than does anencephaly or exomphalos)."

We are thus quite unable to obtain any information of value from a study of the early clinical history of the condition. We are limited to the pathological examination.

The great point which I wish to bring forward here so prominently is that the affection is not only one in which the brain development has been affected and all the other changes secondary to this. Not only is the brain primarily affected, but there are found changes in the spinal cord and medulla, which can only be regarded as a primary change in the spinal cord and in the medulla. This is a point of very great importance. It denotes that the change is not just one affecting the brain, but that it affects the whole cerebro-spinal nervous system. That the spinal cord, medulla, pons and mesencephalon are affected secondarily from changes in the brain is at once evident. This must be so. It is quite unreasonable to expect a normally sized spinal cord with such a reduced brain, but the important point is that not only are there marked secondary changes in the cord, but there are also most interesting conditions present both of the grey matter in the dorsal region, of the white matter, and of the nerve cells, especially of the upper antero-lateral group in the cervical region, which cannot possibly be secondary to the reduced cerebrum and which may be completely understood if regarded as a primary change in the cord itself. There is, ~~for instance~~, a micromyely as well as a microcephaly.

But not only is this the case : the reduction in the amount of medullation of the column of Goll as we ascend the cord is due to a primary change in the posterior nerve cells themselves. Veraguth has shown that there are found fully developed posterior root ganglia in cases of anencephaly, proving that the development of these ganglia is independent of the central nervous system. And an affection of the posterior root ganglia such as is found here is also to be looked upon as a primary condition, since even if the whole cord should be absent, we still find normally developed spinal ganglia. The growth disturbance has not affected the brain alone ; it has affected the whole cerebro-spinal nervous system at the same time in the same manner, and we may classify the changes which have occurred under three headings :

1. The growth has become arrested at the third or fourth month, and in consequence, a smaller and simpler type of brain has developed on the top of the previous condition, and, therefore, on examining the fully formed brain we find all the evidence of this new type of brain, which has a very close resemblance to that of the low ape brain.

2. As the result of the superposition of this ape-brain upon the foetal, there have appeared a number of disturbances which are purely ~~which are purely~~ the mechanical result of this change, and which are typical of the microcephalic brain and of it alone.

3. This superposed type of brain is considerably smaller

than the normal brain which has previously been present. As a result of the growth disturbance and alteration in the nerve cells subsequent to this change, they become adjusted to this smaller type of brain, and as the nerve fibres have already been formed in proportion to the normal sized brain, we have the peculiar condition of nerve cells which have, as a result of an arrest of development, become so enfeebled as to be unable to completely medullate the whole length of the fibres. Thus it is that we have the absence of myeline in the peripheral parts of the fibres, such as the posterior root fibres, the tract of Gowers, tract of Helweg, etc.

From these three facts we obtain a complete explanation of all the features present in the microcephalic brain. In consequence of this we are enabled to regard the cause of this condition from a far wider point of view, as it is at once evident that no explanation which merely applies to the cerebrum alone is sufficient to account for a primary change in the cord and medulla. All such theories as premature closure of the skull, abnormally small carotid arteries, pressure on the foetal head, will account only for primary changes in the cerebrum alone. We must look for some wider cause, and it is necessary that it should be a cause which would be able to act upon the whole cerebro-spinal nervous system at the same time, in the same manner, and to affect each part similarly and separately from the neighbouring parts. There are only two conditions which seem to me to agree with the above facts. First, there has been some change in the blood. Such a change would be able to account for an affection of the whole cerebro-spinal nervous system, and the posterior root ganglia. By a change in the blood, I do not refer to a change in the blood elements, but to the absence of some substance which reaches the nervous system by the blood. Such a substance might be an internal secretion. Some internal secretion which is necessary for the proper metabolism or growth of the foetus may suddenly fail, or become diminished; and, in consequenc the activities of the tissues is correspondingly reduced. They might, thus, be so impaired as to be unable to complete the development originally laid down by nature, and instead, might follow some less highly specialised and therefore simpler path. We know that the normal development may be seriously affected by the absence or increase of an internal secretion. In acromegaly we have an example of an abnormal development which is intimately connected with the internal secretion of the pituitary. But I am quite unable to deduce any exact knowledge in favour of the above view, and the general evidence is rather against than for it. An internal secretion usually has a physiological action upon one particular organ or tissue; in microcephaly the whole organism has been affected, not only have the brain and spinal cord been altered in their natural course of development, the skull and arteries have also been affected; and, the whole evidence is far more in favour of some far deeper cause than this, i.e. the failure of some internal secretion.

It appears to me that the microcephalic idiot must not be looked upon as the result of any pathological lesion, but as the result of some quite unknown cause which has affected the germinal tissue itself. The result of this cause has been to interfere with the normal development of the brain somewhere about the third or fourth month. The brain, or rather, the organism has been unable to continue its normal growth. It has evidently lost its power to develop into the complete typical adult condition; instead its diminished supply of energy, has only been sufficient to produce a smaller and simpler type of organism, and there has been an attempt made to replace the first structures laid down by those of the second. This, however, was not possible, and what has actuaaly happened is that the two structures are found lying side by side together, the later structures superposed upon the the earlier, and causing in many places some very remarkable changes as the result of the mechanical effects so produced.

I have spoken of the growth arrest as occurring at the "third or fourth month". This is the date given by Cunningham. It appears to me to be correct. But it is obvious that there may be changes occurring of a similar nature both before and after this date. If the change should occur after this date, it will at once be seen that the condition will differ from that found in the microcephalic idiot, since the human foetal characteristics will be further developed, and the subsequent alteration in growth will not be able to affect such profound changes as I have just described, if the affection occurs at the third or fourth month, when the brain and cord are in such a condition as to be easily altered. In these latter changes, the human imprint will be more strongly impressed upon the organism and as all the different regions will be more completely formed, they will lend themselves to a very small degree to any subsequent change. And the further the brain developes, the less marked is the change, and possibly some of those cases of idiocy where the brain does not show any marked pathological lesion, and is below the normal weight, may come under this heading.

But, if the growth arrest were to occur before the third month, an entirely different set of conditions will result. At this stage the brain is in a condition where mechanical disturbances will be very readily produced, and what is still more important, a mechanical disturbance at this period in the development will give rise to pathological results from the abnormal conditions to which the brain substance will be subjected, and this probably is the explanation of some of those very extraordinary brains, with an extremely light weight, and which seem to bear such a peculiar resemblance to the very early foetal brain And it is very probably that the earlier the growth alteration is affected, the greater is the difference between the superposed type of brain and the normal.

"Microcephaly proper", therefore, is to be looked upon as a condition in which the growth of the whole organism has been altered at some period about the third or fourth month, after which period, the growth has proceeded along some less highly specialised path.

What the cause of the change which has taken place at the third month is, I cannot tell, It must be looked upon as due to a cause similar to that which produced the occasional presence of a supra-condyloid process in the humerus, or of an extra digit in the foot of the horse, and other such cases. If these are the result of an atavism, then microcephaly proper must also be looked upon as the same. There is no pathological lesion to be found in a humerus which shows such a condition neither is there any pathological lesion the the microcephalic idiot.

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CONCLUSIONS.

I. The microcephalic idiot belongs to a definite natural group, outside the domain of pathology, and characterised by certain morphological features which are always found upon true microcephalic brains.

2. The brain of the microcephalic idiot exhibits a number of changes which may be completely understood if regarded as the result of;-

   I. A growth arrest at the third or fourth month;

   2. A subsequent attempt to replace this brain by a second simpler and smaller type of brain.

   3. This smaller type of brain resembles very closely that found in the lower apes to-day.

   4. As growth proceeds this smaller and simpler type of brain is superposed upon the normal foetal brain.

   5. As a result of this, important mechanical disturbanee are caused, which produce changes in the brain which are ~~only~~ to be found in the microcephalic idiot, and which are characteristic of microcephaly proper.

   6. The arrangement of the fissures and convolutions show a close, but not by any means exact, resemblance to that found in the low apes.

3. The whole of the features found in the microcephalic brain are the result of the superposition of a simpler and ape-like type of brain upon a three or four

moths foetal brain.

4. The spinal cord is primary affected, quite apart and separate from its brain connections. There is a <u>micromyely</u> as well as a <u>microcephaly.</u>
5. The posterior root ganglia are also primary affected.
6. The medulla is also primary affected.
7. In microcephaly proper, the whole cerebro-spinal nervous system has been involved, and, consequently, no explanation which will only account for the change in the cerebrum is of any value.

The microcephalic idiot is a morphological entity.

The changes in the brain are the result of the superposition of a simple ape-like type of brain, upon a foetal brain.

The medulla, spinal cord, and posterior root ganglia are all also primarily affected.

The condition is due to an atavism, and is to be regarded as of the very higest importance in the theory of descent.

NUMBER and SIZE of CELLS in GREY MATTER of CORD of MICROCEPHALE.

	Size of Cells	Number of Cells
III. Cervical Segment		
Spinal Accessory Nucleus	2.5 μ	3
Antero-mesial Group	4.5 μ	4
IV. Cervical Segment		
Phrenic Nucleus	6.0 μ	12
Spinal Accessory Nucleus	4.5 μ	4
Antero-mesial group	2.6 μ	6
V. Cervical Segment		
Antero-mesial group	4.5 μ	6
Antero-lateral group	--	---
Postero-lateral group	8.4 μ	25
Cervical nucleus of Stilling	10.4 μ	2 - 4
VI. Cervical Segment		
Antero-mesial group	4.7 μ	2
Postero-mesial group	5.6 μ	2
Upper antero-lateral group	---	---
Lower antero-lateral group	14.2 μ	8
Postero-lateral group		17
Cervical nucleus of Stilling	11.5 μ	2

	Size of Cells	Number of cells
VII. Cervical Segment		
Antero-mesial group	5.0 μ	6
Postero-mesial group	4.1 μ	3
Lower antero-lateral group	13.7 μ	18
Postero-lateral group	14.5 μ	7
Cervical nucleus of Stilling	12.0 μ	2
VIII. Cervical Segment		
Antero-mesial group	4.5 μ	3
Postero-mesial group	5.1 μ	1
Antero-lateral group	16.7 μ	10
Postero-lateral group	19.3 μ	27
Post-postero-lateral group	8.0 μ	4
Cervical nucleus of Stilling	13.5 μ	2
I. Dorsal Segment		
Antero-mesial group	8.2 μ	6
Antero-lateral group	10.6 μ	4
Postero-lateral group	15.2 μ	15
Intermedio-lateral tract		13
Clarke's column	7 - 16 μ	4
II. Dorsal Segment		
Antero-mesial group	5.4 μ	5
Antero-lateral group	14.5 μ	5
Post-postero-lateral group	15.3 μ	11
Intermedio-lateral tract		17
Clarke's column	12.3 μ	2

	Size of Cells	Number of Cells
III. Dorsal Segment		
Antero-mesial group	13.7 μ	13
Postero-mesial group	5.6 μ	2
Intermedio-lateral tract	32.5 μ	29
Clarke's column	5 - 15 μ	4
IV. Dorsal Segment		
Antero-mesial group	12.2 μ	7
Postero-mesial group	4.7 μ	2
Intermedio-lateral tract	4.6 μ	26
Clarke's column	9.2 μ	7
V. Dorsal Segment		
Antero-mesial group	11.0 μ	10
Postero-mesial group	3.9 μ	3
Intermedio-lateral tract	5.4 μ	24
Clarke's column	8.6 μ	7
VI. Dorsal Segment		
Antero-mesial group	8.7 μ	7
Postero-mesial group	3.4 μ	3
Intermedio-lateral tract	6.2 μ	18
Clarke's column	8.9 μ	10

	Size of Cells	Number of Cells
VII. Dorsal Segment		
Antero-mesial group	7.4 μ	5
Postero-mesial group	2.8 μ	4
Intermedio-lateral tract	6. μ	10
Clarke's column	9.3 μ	9
VIII. Dorsal Segment		
Antero-,esial group	8.5 μ	6
Postero-mesial group	3.9 μ	2
Intermedio-lateral tract	6.4 μ	17
Clarke's column	10.2 μ	15
IX Dorsal Segment		
Antero-mesial group	9.0 μ	5
Postero-mesial group	4.1 μ	2
Intermedio-lateral tract	5.7 μ	19
Clarke's column	11.6 μ	13
X. Dorsal Segment		
Antero-mesial group	6.9 μ	3
Postero-mesial group	4.8 μ	2
Intermedio-lateral tract	7.3 μ	24
Clarke's column	11.9 μ	11

	Size of Cells	Number of Cells
XI. Dorsal Segment		
Antero-mesial group	7.4 μ	5
Postero-mesial group	3.8 μ	2
Intermedio-lateral tract	5.4 μ	19
Clarke's column	11.6 μ	9
XII Dorsal Segment		
Antero-mesial group	10.1 μ	5
Postero-mesial group	5.6 μ	2
Intermedio-lateral tract	7.2 μ	20
Clarke's column	13.2 μ	17
I. Lumbar Segment		
Antero-lateral group	8.4 μ	5
Postero-mesial group	9.2 μ	3
Intermedio-lateral tract	7.1 μ	12
Clarke's column	13 - 17 μ	12
II. Lumbar Segment		
Antero-mesial group	9.8 μ	5
Antero-lateral group	12.3 μ	4
Intermedio-lateral tract	8. μ	5
Clarke's column	18 μ	17

	Size of Cells	Number of Cells
III. Lumbar Segment		
Antero-mesial group	5.6 μ	2
Antero-lateral group	14.1 μ	9
Postero-lateral group	12.2 μ	7
Clarke's column	18.7 μ	5
IV. Lumbar Segment		
Antero-mesial group	3.1 μ	2
Antero-lateral group	18.4 μ	20
Postero-lateral group	19.6 μ	17
Central group	16.2 μ	7
V. Lumbar Segment		
Antero-mesial group	4.2 μ	3
Antero-lateral group	16.9 μ	14
Postero-lateral group	17.8 μ	27
Central group	19.2 μ	7
I. Sacral Segment		
Antero-mesial group	3.6 μ	2
Antero-lateral group	17.2 μ	3
Postero-lateral group	20.3 μ	25
Post-postero-lateral group	12.2 μ	2
Central group	16.4 μ	9

	Size of Cells	Number of Cells
II. Sacral Segment		
Antero-mesial group		0
Antero-lateral group	16.4 μ	13
Postero-lateral group	22.6 μ	13
Post-postero-lateral group	20.1 μ	8
Central group	15.7 μ	17
III. Sacral Segment		
Antero-mesial group	3.7 μ	4
Antero-lateral group		0
Postero-lateral group	18.7 μ	10
Post-postero-lateral group	19.5 μ	22
IV. Sacral Segment		
Antero-mesial group	5.4 μ	6
Antero-lateral group		0
Postero-lateral group		0
Post-postero-lateral group	14.2 μ	3

V. Sacral Segment

No motor cells present.

These measurements given above were made with a Leitz micrometer eye-piece, the tube of the microscope being at 170 mm., and the lens No.6.

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